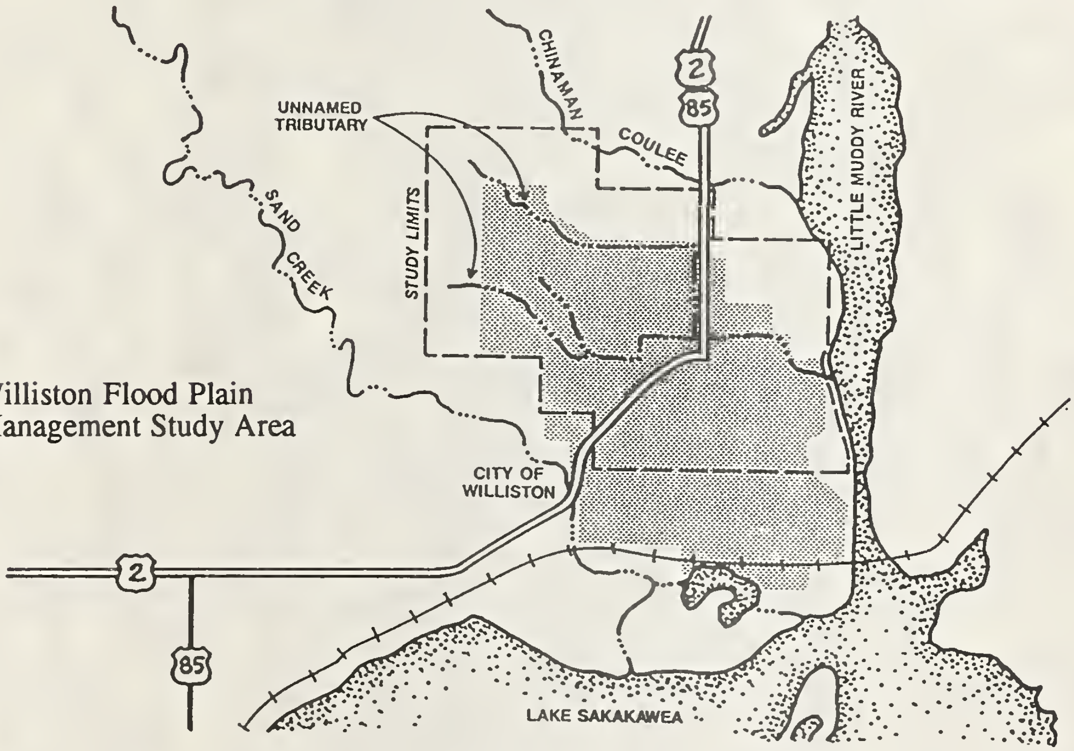
'lood Plain Management Study

For An Unnamed Tributary Through The

City of Williston
Williams County, North Dakota



Prepared for:
City of Williston
Williams County Water Resource District

In cooperation with:
City of Williston
Williams County Water Resource District
Williams County Soil Conservation District
North Dakota State Water Commission
Private Citizens

USDA - SOIL CONSERVATION SERVICE
Bismarck, North Dakota
September 1993

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FOREWORD

This report defines the flood characteristics of an unnamed tributary of Lake Sakakawea, a reservoir on the Missouri River. The runoff flows through Williston, North Dakota, in a general northwest to southeast direction. Williston lies in Williams County, in the northwestern portion of the state.

The study defines the flood hazard of lands and developments along the unnamed tributary. This existing flood hazard is the basis used for the planning of measures to eliminate or reduce flood damages.

Land uses along the unnamed tributary include transportation, residential, commercial, industrial, agricultural, recreational, and wildlife. Despite recent slowing of the local energy industry, it is anticipated there will be continued pressure for development of the flood plain.

This cooperative report was prepared as a guide for local officials in planning land use and regulating development within the flood plain. The 10-, 50-, 100-, and 500-year frequency flood events were selected to represent degrees of major flooding that could occur in the future. The 100-year[1] and the 500-year[2] floods are frequencies considered for land use planning and development in the flood plain. Potential flooded areas are defined by flood hazard photomaps that show the approximate areas subject to inundation. Flood profiles show the water surface elevations for the selected events. Typical valley cross sections are presented to indicate ground levels across the width of the valley with the overlying flood depths. The flood profiles and flooded area photomaps are based on conditions at the time of study.

This report does not imply any federal authority to zone or regulate use of the flood plain; authority to zone and regulate rests with state or local governments. Technical data is provided for the potential future adoption of local land use controls to regulate flood plain development. This report identifies flood problems and gives environmentally sound guidance for the development of flood damage reduction techniques, such as flood control structures, removal of obstructions, and floodproofing for use in an overall flood plain management program.

The assistance and cooperation of the Williams County Water Resource District, Williams County Soil Conservation District, city of Williston, North Dakota State Water Commission, U.S. Army Corps of Engineers, and private citizens in carrying out this study are appreciated.

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[1] A flood which has a 1 percent chance of being equaled or exceeded in any year (also called "base" flood).

[2] A flood which has a 0.2 percent chance of being equaled or exceeded in any year.

INTRODUCTION

The purposes of this cooperative study are to define flood characteristics along an unnamed tributary of the Missouri River in the city of Williston, Williams County, North Dakota, and provide technical data necessary to implement an effective local flood plain management program.

Nonregulated development and encroachment frequently reduce flood conveyance, thereby increasing flood stages and overall flood damages. This report defines the existing flood hazard to lands and developments along the unnamed tributary. This existing flood hazard is the basis used for the planning of measures to eliminate or reduce flood damages.

It is imperative that flood plains in both urban and rural areas be defined so that the planning and location of valuable properties can be controlled and areas identified where future flood control measures can be applied. Many financial institutions are reluctant to lend money to persons in flood plains, since the advent of federal laws governing financing within flood plains. Federal agencies cannot finance projects in these communities, unless there is assurance that the area is flood free or can be protected.

This flood plain management study was requested by the city of Williston, Williams County Water Resource District, and the Williams County Soil Conservation District, through the North Dakota State Water Commission, under the 1978 Joint Coordination Agreement with the Soil Conservation Service (SCS). Priorities regarding such studies are set by the North Dakota State Water Commission. The study was carried out in accordance with the June 1986 Plan of Study between the above mentioned entities.

The study consists of 4.60 total channel miles, from the confluence with a Corps of Engineers protective levee system and pumped storage along the east edge of Williston to the west edge of the city (see map).

The Main Tributary extends 3.72 miles from the SW¼ of Section 18, Township 154 North, Range 100 West (Mile 0.00) to the S½ of Section 10, Township 154 North, Range 101 West (Mile 3.72). The U.S. Highway 2 & 85 Ditch follows the E½ of Section 11, Township 154 North, Range 101 West, joining the Main Tributary at mile 2.10 (0.88 mile reach length).

WILLISTON FLOOD PLAIN MANAGEMENT STUDY

The "Extra Territorial Jurisdiction Law", passed by the 1975 North Dakota Legislature, provides communities with zoning authority outside the corporate limits (reference 6). The zoning authority for the city of Williston includes the Williston Flood Plain Management Study Area.

Authority for this study is in accordance with Federal Level Recommendation 3 of "A Unified National Program for Flood Plain Management" (reference 2), and Section 6 of Public Law 83-566 (reference 11). In carrying out this study, the Soil Conservation Service is responsive to Executive Order No. 11988 (reference 5), which directs that "all executive agencies responsible for programs which entail land use planning shall take flood hazards into account when evaluating plans and shall encourage land use appropriate to the degree of hazard involved."

Potential users of flood plains should base planning decisions upon the advantages and disadvantages of each location. Potential flood hazards are often unknown and consequently the managers, potential users, and occupants cannot always accurately assess these risks. In order for a local flood plain management program to be effective in the planning, development, and use of flood plains, it is necessary for the SCS to:

1. Assist state and local units of government by preparing appropriate technical information and interpretations for use in their flood plain management programs.

2. Provide technical services to managers of flood plain property for present and future land uses.

3. Improve basic technical knowledge about flood hazards in cooperation with other agencies and organizations.

This report contains aerial photomaps, water surface profiles, and typical valley and channel cross sections indicating the extent of flooding that can be expected along reaches of the tributary. The 10-, 50-, 100-, and 500-year frequency flood discharges and elevations are included.

The North Dakota State Water Commission or the Soil Conservation Service will, upon request, provide technical assistance to federal, state, and local agencies and organizations in the interpretation and use of the information contained in this study.

DESCRIPTION OF STUDY AREA

The study area of the Williston Flood Plain Management Study is located solely in the city of Williston in the Water Resource Council's Missouri River Region and Subregion 10110101. The unnamed tributary analyzed in the study is an ephemeral stream, flowing only during rainfall or snowmelt runoff events.

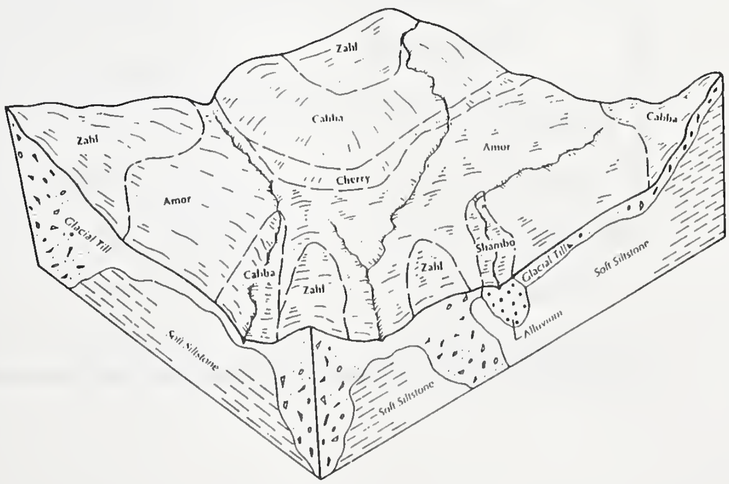
The Williston region is situated on the southern edge of the Great Plains Physiographic Province. The area consists essentially of a broad rolling, glacial drift covered upland incised by the Missouri River and the Little Muddy and Sand Creeks. Elevations range from about 1840 msl at the tributary outlet to about 2100 msl on the uplands.

The pre-Pleistocene drainage system in the region flowed in a general north and northeast direction, entrenched to an elevation of about 1600 msl. With the advance of the glaciers during the Pleistocene period, the northern outlet was probably blocked, forcing the stream outlet to the southeast. Subsequent to these river changes, at least 200 feet of alluvium was deposited in the Missouri River and Little Muddy Creek valleys.

The upper portions of the drainage area consist of glacial drift, composed of both till and glaciofluvial deposits. The till generally consists of a sandy clay with a small percentage of stones from gravel to boulder in size. Most of the sandy clay material appears to have been derived from the Fort Union formation. Gravels and larger materials are foreign to the area. Glaciofluvial deposits include varying combinations of sand and gravel with some cobble size material. Gravel particles are generally rounded to subrounded, partly weathered, and may be of igneous, sedimentary, or metamorphic origin.

The Fort Union formation of Tertiary (Paleocene) Age forms the bedrock in the area. The formation, with a maximum thickness of approximately 1,000 feet, consists essentially of flat lying, partially indurated deposits of gray clay, brown to brownish gray fine sands, and lignite beds. The clay and sand horizons are discontinuous, often cross bedded, and vary from thin partings to over 15 feet thick. There is little cemented rock, although concretionary horizons and some layers of thin limestone and sandstone are present. Lignite beds, varying from thin partings to over 10 feet thick, are extensively jointed and cracked and are the principal water bearing horizons in the Fort Union.

Soils in the Williston area, above the lake plain, are generally of the Amor-Zahl-Cabba Association. Typical pattern of these soils and underlying material are shown in the figure to the right. For descriptions or characteristics of soils, contact the Williams County SCS office. The Williams County Soils Survey is scheduled for publication in December 1993.



Climate of the area is considered semi-arid to sub-humid and continental, characterized by long winters and warm summers. Average summer and winter temperatures are about 70°F and 10°F, respectively, with extremes recorded from 109°F to -50°F.

The following tables show pertinent analyses using Soil Conservation Service methods (reference 3), using weather data from the Williston Airport, National Weather Service WSO Station 9425, years 1949-1991.

Month	Temperature					Precipitation			
				2 years in 10 will have			2 yrs in 10 will have		average number of days with 0.10 inch or more
	avg daily max	avg daily min	avg	max temp. >than	min temp. <than	avg (in.)	less than (in.)	more than (in.)	
January	18.5	-2.1	8.2	47	-36	0.57	0.24	0.85	1
February	25.9	5.1	15.5	54	-28	0.44	0.16	0.68	1
March	37.4	16.6	27.0	70	-18	0.67	0.24	1.02	2
April	55.1	30.7	42.9	85	6	1.19	0.40	1.83	3
May	67.7	42.5	55.1	94	24	1.80	0.61	2.78	4
June	76.8	51.7	64.3	97	35	2.54	1.37	3.57	5
July	84.2	57.1	70.6	103	42	1.93	0.88	2.83	4
August	82.8	54.9	68.8	102	38	1.32	0.53	1.99	3
September	69.9	43.5	56.7	96	25	1.34	0.39	2.11	3
October	57.8	32.6	45.2	84	11	0.76	0.23	1.26	1
November	38.3	17.8	28.0	67	-13	0.48	0.17	0.75	1
December	24.6	4.6	14.6	52	-31	0.54	0.26	0.78	1
Yearly :									
Average	53.2	29.6	41.4						
Extreme	109	-50		105	-37				
Total						13.57	10.72	16.27	29

Average annual precipitation ranges from approximately 11 to 16 inches, with snow comprising about 4 inches of the total. Most of the precipitation is received in the form of rainfall between the months of April and September. Summer thunderstorms are often intense and accompanied by hail.

Probability	Daily Minimum Temperature, Fahrenheit		
	# days > 28°	# days > 28°	# days > 32°
9 years in 10	144	129	108
8 years in 10	150	135	115
5 years in 10	161	147	130
2 years in 10	172	159	144
1 year in 10	177	165	152

The growing season is approximately 130 days, with average last killing frost on May 17 and earliest on September 23. Relatively large extremes in the weather can occur rapidly with the frequent passage of weather systems across the area.

Probability	Temperature, Fahrenheit		
	24^{o} or lower	28^{o} or lower	32^{o} or lower
Last freezing temperature in spring :			
1 year in 10 later than -	May 7	May 14	May 30
2 year in 10 later than -	May 2	May 10	May 24
5 year in 10 later than -	April 22	May 1	May 14
First freezing temperature in fall :			
1 yr in 10 earlier than -	September 23	September 15	September 8
2 yr in 10 earlier than -	September 29	September 20	September 12
5 yr in 10 earlier than -	October 9	September 30	September 22

Major land uses in the study drainage area are comprised of 25.6 percent pastureland and rangeland, 28.3 percent cropland, 32.3 percent urban residential land, 9.4 percent commercial land and industrial land, 2.3 percent recreational land, and 2.1 percent transportation land. Land uses in the flood plain are primarily residential and commercial properties.

NATURAL VALUES

Flood plains including their land and water ecosystems, have evolved from natural forces over tens of thousands of years. Yet, after two centuries of our Nation's history, the natural values of most of our flood plains have been significantly altered. Thus, there is a national concern to carefully manage the remaining natural values of flood plains. [1]

In urban and rural areas, clearing of wooded areas, wetland drainage, fall tillage, conversion of grassland to cropland, and drainage ditches contribute to flooding problems and existing flood damage. In addition, various modification to existing land use add to erosion in the headwater areas and corresponding sedimentation in the lower reaches of the study area. [2]

The Williston Flood Plain Management Study consists of the flood plains and similar adjacent resource areas in and adjacent to the city of Williston. The natural values discussion includes mostly areas in or zoned for urban development and in the upper reaches of the study, suburban/rural areas.

Wetlands remaining in the upper reaches of the watershed are primarily located in the adjacent drainages associated with Chinaman Coulee, Sand Creek, and lesser drainages as they outlet into Little Muddy River and Missouri River. In the lower drainage reaches, the major wetlands remaining in the study area are those associated with the Little Muddy River and the Missouri River.

No critical habitats for threatened or endangered species were identified in the study area.

Cultural resources impacts are and have often been overlooked, especially those resulting from flood plain development and modification. Historical, archeological, and scientific, and aesthetic sites are often degraded or destroyed by accelerated runoff, blocked runoff, interrupted groundwater flow, and increased pollution loadings. Poor agricultural land use practices can be just as destructive to flood plain values as the more obvious structural forms of development. [3]

A cultural resources survey has not been made specifically for the tributaries and their flood plains; however, as of May 9, 1989, there were 1,351 sites and 1,338 site leads in the state computerized site date file for the Garrison Study Unit.

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1 "A Unified National Program for Flood Plain Management," March 1986, Federal Emergency Management Agency, Interagency Task Force on Flood Plain Management.

2 "Interagency Hazard Mitigation Team Report", July 1989, North Dakota State Water Commission.

3 "North Dakota Comprehensive Plan for Historic Preservation: Archaeological Component" January 1990, State Historical Society of North Dakota.

Soil mapping units considered to be prime farmland or prime farmland where drained include the following: 3 - Tonka silt loam, 13 - Hamerly-Tonka complex, 27 - Arnegard loam, 29 - Wildrose cloay, and 85 - Hamerly loam. These soil mapping units make up a little more than 2 percent of the county. The study has no prime farmland acres.

Commonly grown crops in the upper part of the study area are small grains. Alfalfa, smooth bromegrass, crested wheatgrass, and native grasses are grown as livestock feed sources. Other grasses and woody vegetation are grown for ornamental purposes in the more suburban and urban areas.

Tree and shrub species occurring in the study area are typical deciduous and coniferous species occurring in the northern plains. Most occur as field and farmstead windbreaks or as urban ornamentals. Scattered clumps of naturally occurring woody species, such as western snowberry, chokecherry, buffaloberry, boxelder, Russian olive, cottonwood, elm, and willow species occur in the study area.

Wildlife expected to occur in the study area include game birds such as gray partridge, ring-necked pheasant, waterfowl, mourning dove, sharp-tailed grouse, and sandhill crane; and non-game birds such as American robin, meadowlark, rock dove, gull, tern, hawk, owl, crow, nighthawk, killdeer, swallow, martin, chickadee, avocet, snipe, phalarope, flicker, kingbird, flycatcher, phoebe, wood pewee, lark, magpie, wren, catbird, thrush, vireo, warbler, grosbeak, bunting, cowbird, and sparrow.

Mammals might include red fox, coyote, antelope, mule deer, whitetail deer, muskrat, mink, raccoon, badger, weasel, eastern cottontail, whitetail jackrabbit, shrew, bat, skunk, prairie dog, ground squirrel, pocket gopher, woodrat, vole, and mice.

Reptiles might include snapping and painted turtles; short-horned lizard; prairie skink; snakes such as the common garter, western hognose, racer, and rattlesnake; and amphibians might include tiger salamander, plains spadefoot toad, great plains toad, Woodhouse's toad, chorus, and leopard frog.

Naturally occurring beneficial flood plain values in the study area have been significantly affected by human actions. These actions have removed conditions under which natural processes can continue. Some of those actions include wetland destruction, paving, roofing, overgrazing, deep foundations, buildings, roads, dikes and dams, as well as fertilizers, chemical and petroleum spills, and leached products of waste disposal areas.

Flood plain natural values management and re-establishment should be considered in the study area. The following examples of practices would be beneficial to flood plain values:

1. Minimize filling in the flood plain.

2. Relocate structures out of the flood plain.

3. Restore and preserve natural drainage routes.

4. Restore damaged wetlands and prevent additional wetland destruction and channelization.

5. Support agricultural and urban practices that minimize water quality degradation, such as controlled use of pesticides and fertilizers.

6. Limit field size. Promote fence rows, field windbreaks, and strip cropping.

7. Design structural upstream projects for runoff detention.

8. Re-establish damaged flood plain ecosystems.

9. Maintain existing riparian vegetation as a green belt.

FLOOD PROBLEMS

The Williston area economy is primarily agricultural, although energy exploration and production also provide a significant contribution. The area is heavily influenced by cycles in the oil industry, with the most recent oil boom occurring from the late 1970s through the mid 1980s. The following table shows historic population trends.

POPULATION OF WILLISTON

YEAR	1910	1920	1930	1940	1950	1960	1970	1977	1980	1990
POPULATION	3,124	4,178	5,106	5,790	7,378	11,866	11,280	11,771	13,336	13,131

Flooding is often expected to occur in the spring of the year, usually April. Heavy accumulations of snow and frozen soil conditions are likely. Flooding conditions can be further aggravated by the combination of spring rains with rapid snowmelt. The most recent flood problems, however, were experienced during rainfall events in the summers of 1986, 1987, and 1993.

Developments during the most recent increase in oil production, 1979 to 1985, included residential and industrial expansion along the west, north, and south sides of Sloulin International Airport. Developments include a combination of surface and subsurface stormwater removal. No comparison of present and previous conditions is made as part of this study; however, the subsequent roadways, rooftops, and other surficial and drainage pattern changes are assumed to have an effect on runoff conditions.

Primary land uses on flooded areas include agricultural, urban, and transportation. Agricultural lands within the study area are attractive to development due to the close proximity to services and view offered. Existing adjacent urban developments typically include high value homes and property.

The most recent flooding within the basin occurred in 1986, 1987, and 1993. The study area was not recognized as flood prone before then. Flood plain management studies were completed for the adjacent watersheds of Sand Creek and Chinaman Coulee in 1982 (see map).

EXISTING FLOOD PLAIN MANAGEMENT

Existing flood plain management in Williston has been responsive to community needs and consistent with land use and zoning regulations. Township, county, and state agencies, such as the sponsors of this report, are acutely aware of potential flooding problems. The responses by city officials to flood problems identified during 1986 and 1987 flood events are indicative of their commitments.

In 1988, the city of Williston and the Sloulin International Airport made improvements to the airport and upstream drainage channels, and constructed a temporary holding pond on the north side of the airport. The channel improvements resulted in better control and removal of overland flows into Sand Creek and south along 16th Avenue. The pond reduces peak discharges, reducing the threat of flooding, especially along the commercial area between Sloulin Airport and U.S. Highway 2 & 85. These improvements are located in general plan view on page G-2, Appendix G.

Williston has a storm water system consisting of both subsurface pipe and surface channels. The existing system is adequate for the more frequent events; however, they can not alleviate flood plain problems for infrequent flood events. The complexity of the surface and subsurface stormwater systems is illustrated on page G-6, Appendix G. Outlets converge at the intersection of U.S. Highway 2 & 85 and 26th Street, enter a common drainage channel, which ultimately outlets into the COE pumped storage area (mile 0.00).

Several diversion structures have been constructed to reduce potential flooding damages. Brief descriptions are as follows:

> The diversion at the northwest edge of the Sloulin International Airport, commonly called the "keyhole area" because of its shape, diverts water south to 16th Avenue. This prevents overland flooding of airport runways, taxiways, and buildings.
>
> The temporary pond at the north edge of the airport stores runoff from the northwest and effectively reduces flows downstream. Capacity of the pond is shown on page G-1, Appendix G.
>
> At 16th Avenue and 26th Street, a portion of the flows are diverted south through the "16th Avenue outfall" into Sand Creek. These features are shown in the general plan view on page G-3, Appendix G.
>
> Upstream drainage is also diverted from the watershed along the south edge of the center of section 10, through 26th Street, into Sand Creek, via the "Hagan Slingsby Ditch." This diversion is shown in general plan view on page G-4, Appendix G.
>
> The "34th Street Outfall," a pipe conduit stormwater diversion, is shown in the general plan view on page G-5, Appendix G. It diverts water from the west side of Highway 2 & 85 to the east and south and bypasses several city streets and Highway 2 & 85.

The features listed above are also located on the general plan view of the Sloulin International Airport, page G-2, Appendix G.

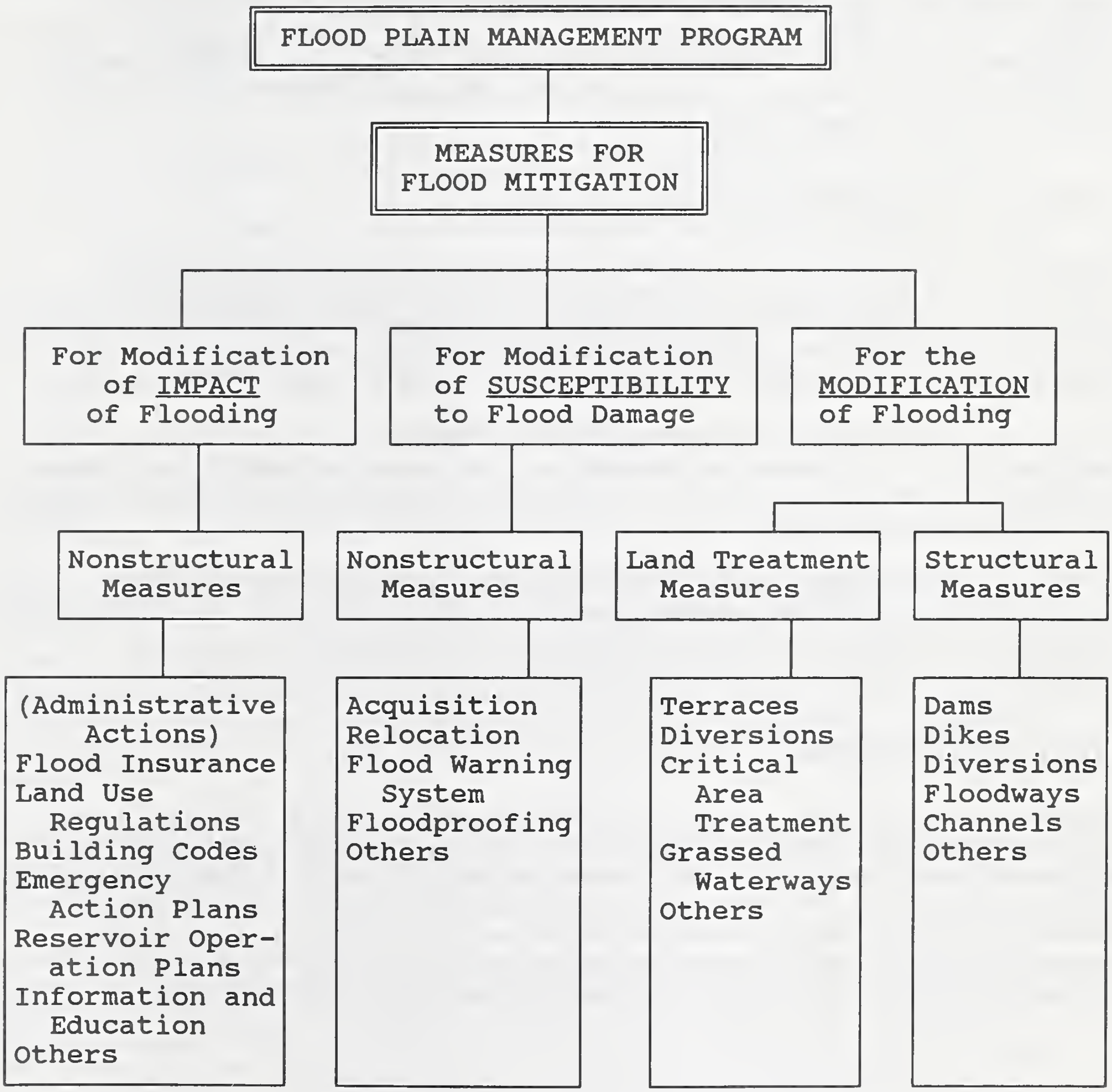
At 42nd Street, a 36-inch diameter pipe conduit diverts water through Highway 2 & 85, from west to east, out of the drainage basin. This pipe is not shown in Appendix G.

Three dams exist northwest of the airport, on the north edge of the golf course. The three dams were apparently constructed during former gravel mining operations. The largest of the three structures has sufficient capacity to be considered significant for this study, the other two dams are not considered. The large dam stores essentially all the upstream runoff for most storm events, if empty when runoff occurs. It does not meet existing dam building criteria. Because of its size, an analysis was made to determine the downstream effects that would occur if it were to breach (fail). There is no apparent threat to loss of life because of its remote location. Discharges would spread out over the airport property, with resultant downstream flood stages at or less than those shown on the photomaps. The city and/or owner should, however, consider removing or replacing it with a more suitable dam to prevent the possibility of failure and resulting downstream damages. Specific storage capacities for the dam are shown on page G-1, Appendix G.

Williston has previously completed the Sand Creek and Chinaman Coulee Flood Plain Management Studies. With the completion of this study, Williston will have city-wide coverage of the recognized flood plains, except for the drainage area adjacent to and serviced by the 16th Avenue ditch.

ALTERNATIVES FOR FLOOD PLAIN MANAGEMENT

Potential solutions to reduce or mitigate identified problems include land treatment, and nonstructural and structural measures. The flood plain management flow chart below depicts the interrelationship of flood mitigation measures.



It is important that the community takes action to implement other programs and measures to supplement administrative actions. A few measures to protect and control developments in flood prone areas are: (1) open space land acquisition, (2) urban renewal programs, and (3) preferential tax assessment.

With flood hazard information, Williston can minimize future flood losses by planning for the protection, wise use, and orderly development of the flood plain area. A coordinated planning procedure is a vital part of any comprehensive flood plain management program. Effective flood plain management involves public policy and action for the wise use and development of the flood plain. It also includes the collection and dissemination of flood control information, acquisition of flood plain lands, construction of control structures, and enactment of ordinances and statutes regarding flood plain land use and development.

Until revised flood areas are specified through the Federal Emergency Management Agency (FEMA) Regular Flood Insurance Program, owners should continue to maintain flood insurance to protect their investments. Individual property owners in unprotected areas are responsible for obtaining flood insurance from a state certified insurance agency. Lenders are often reluctant to make loans unless the nature of the flood plain status is known.

PRESENT CONDITIONS (no action)

Flood plain ordinances and zoning will continue to restrict development in identified flood prone areas and control modifications to existing flood plain structures. The state and federal emergency management agencies will continue to help existing and prospective owners identify whether they are required to maintain insurance coverage. Studies, such as this one, assist in this process.

Design hydraulics assume freeflow conditions. Debris and excess vegetation in the channels can aggravate the situation, such as would occur with poor channel maintenance. Without any action, these problems will remain the same or could increase slightly over time.

Costs associated with this alternative (no action) are the individual cost to landowners who purchase flood insurance and existing operation and maintenance expense. The results are continued damages and reliance on emergency assistance programs for partial recovery of damages.

LAND TREATMENT

Land treatment practices in the upstream watershed have the potential for flood reduction benefits. These practices include both vegetative (nonstructural) and engineering (structural) practices. Due to the large numbers of potential practices and the variability of their use, they are not described in detail for this study. Specific structural practices such as terraces and diversions can store and/or remove the floodwater. Tillage and vegetative practices such as cropland conservation tillage and residue management can affect runoff volumes.

PRESERVATION OF NATURAL VALUES

Management and reestablishment of flood plain natural values should be considered in the study area. The following examples of practices would be beneficial to flood plain values:

1. Minimize filling in the flood plain.
2. Relocate structures out of the flood plain.
3. Restore and preserve natural drainage routes.
4. Restore damaged wetlands and prevent additional wetland destruction and channelization.
5. Implement agricultural and urban practices that minimize water quality degradation, such as controlled use of pesticides and fertilizers.
6. Limit field size. Promote fence rows, field windbreaks, and strip cropping.
7. Design structural, upstream projects for runoff detention.
8. Reestablish damaged flood plain ecosystems.
9. Maintain existing riparian vegetation as a green belt.

NONSTRUCTURAL MEASURES

Primary nonstructural measures consist of administrative actions such as zoning, building codes, flood insurance, flood warning systems, and floodproofing.

Administratively, an annual notification could be provided to property owners to make them more aware of their flood plain status and to serve as a reminder that their property requires flood insurance to defray property losses. Notification could be achieved by a message on property tax notices or on utility service charge bills.

Flood warning time is generally insufficient to construct temporary dikes and levees. Local radio and television can provide limited flood warnings, using up-to-date information based on weather predictions.

Floodproofing individual structures has proven to be cost effective in other areas, depending on depth of flooding and property value. It is anticipated that certain properties in the study area could be floodproofed. Additional information regarding floodproofing methods, specific programs, and assistance is available from either the State Water Commission or the Soil Conservation Service.

STRUCTURAL MEASURES

Several structural features are recognized that would assist flood protection in the study area. These include:

1. A regular maintenance program to remove debris from channels and structures would help maintain channel flow area and prevent potential blocking at bridges and culverts. Routine maintenance is currently done.

2. Improving hydraulic characteristics of channels by enlarging them is a way to increase channel capacity. Care must be taken to ensure that channel stability is maintained. Environmental guidelines must be observed.

3. Increase the area of bridge and culvert openings to minimize the restriction of large floods. The following comparison shows existing and potential 100-year and 500-year water surfaces with bridge modifications at 26th Street (mile 1.22), University Drive (mile 1.57) and U.S. Highway 2 & 85 (mile 2.08). Modified water surfaces assume full flow capacity, no head loss.

Channel miles with bridges or culverts have two elevations shown - the first is downstream of the road or highway, the second is upstream.

Channel mile 0.99 is East Parkway, 1.22 is 26th Street, 1.57 is University Drive, 1.98 is 1st Avenue, and 2.08 is U.S. Highway 2 & 85.

Culverts at mile 0.99 have 7.2 total feet head loss for the 100-year flow. The channel is entrenched at this location, and no existing 100-year flood damages are recognized. Therefore no modification of existing conditions are shown on the adjacent comparison table.

CHANNEL MILES	100-YR ELEVATION (MSL)		500-YR ELEVATION (MSL)	
	EXISTING	MODIFIED	EXISTING	MODIFIED
0.44	1848.6	1848.6	1849.0	1849.0
0.56	1848.9	1848.9	1849.4	1849.4
0.70	1849.3	1849.3	1849.7	1849.7
0.83	1849.4	1849.4	1849.8	1849.8
0.94	1849.6	1849.6	1850.1	1850.1
0.97	1849.8	1849.8	1850.2	1850.2
0.99	1850.1	1850.1	1850.6	1850.6
0.99	1857.3	1857.3	1858.0	1858.0
1.02	1857.3	1857.3	1858.0	1858.0
1.12	1857.4	1857.4	1858.1	1858.1
1.18	1857.6	1857.6	1858.3	1858.3
1.22	1857.8	FREE SPAN	1858.5	FREE SPAN
1.22	1861.1	BRIDGE	1861.5	BRIDGE
1.30	1861.1	1858.6	1861.6	1859.2
1.42	1861.2	1859.7	1861.8	1860.2
1.51	1863.3	1863.0	1863.6	1863.3
1.57	1865.8	FREE SPAN	1866.2	FREE SPAN
1.57	1867.9	BRIDGE	1868.3	BRIDGE
1.67	1869.5	1868.6	1870.3	1869.4
1.76	1870.1	1869.7	1870.9	1870.6
1.93	1870.6	1870.5	1871.5	1871.3
1.98	1870.9	1870.8	1871.7	1871.5
1.98	1871.7	1871.6	1872.1	1872.0
2.02	1871.7	1871.7	1872.1	1872.1
2.06	1871.7	1871.7	1872.1	1872.1
2.08	1871.8	FREE SPAN	1872.3	FREE SPAN
2.08	1873.9	BRIDGE	1874.4	BRIDGE
2.10	1873.9	1871.9	1874.4	1872.3
2.12	1873.9	1872.2	1874.5	1872.6
2.12	1873.9	1872.5	1874.5	1872.9
2.24	1878.2	1878.2	1878.6	1878.5
2.33	1882.9	1882.9	1883.1	1883.1
2.49	1891.8	1891.8	1892.1	1892.1
2.59	1895.0	1895.0	1895.8	1895.8

Mile 1.98 has bridge capacity such that the 100-year head loss is only 0.8 foot, with relatively minor flood effect. When replacement takes place, however, a larger bridge with less head loss would be recommended. No modification of existing conditions for mile 1.98 is shown on the above comparison table.

University Avenue overtops to the east and south at the 26th Street intersection. Replacing culverts with a bridge at University Avenue could reduce the upstream elevation by as much as 2 feet. This 2 feet is significant because of the relative flatness of the channel grade and surrounding topography. Flood flows travel along the south side of 26th Street, and overland through residential areas via streets, following the south and east trending slopes.

U.S. Highway 2 & 85 overtops by about 0.8 foot during the 100-year event, near the intersection with 26th Street. A new bridge could prevent this overtopping and the subsequent flows along the south side of 26th Street. These flood flows, like those overtopping 26th Street at University Avenue, ultimately travel overland through residential areas via streets to the east and south.

4. Other structural improvements were not investigated in detail as part of this study. Examples of improvements include regrading highway and street surfaces to prevent overtopping (with culvert enlargements), diking along existing channels to contain flood flows (to FEMA requirements), additional upstream storage, or further diversion work. The economic benefits of structural improvements were not analyzed.

GLOSSARY OF TERMS

ACRE-FOOT » The amount of water that will cover one acre to a depth of one foot. One acre-foot equals 43,560 cubic feet.

AVERAGE ANNUAL DAMAGE » The estimated yearly damage expected to occur during the evaluation period.

BACKWATER » The resulting high water surface in a given stream due to a downstream restriction or high stages in an intersecting stream.

BASE FLOOD ELEVATION (BFE) » The elevation for which there is a one percent chance in any given year that flood levels will equal or exceed it. The BFE is also known as the 100-year flood.

BUILDING CODE » Regulations adopted by local governments that establish standards for construction, modification, and repair of buildings and other structures.

CHANNEL » A natural or artificial watercourse with definite bed and banks to confine and conduct continuously or periodically flowing water.

CUBIC FEET PER SECOND (CFS) » Rate of fluid flow at which one cubic foot of fluid passes a measuring point in one second.

DISCHARGE » The rate of flow or volume per unit of time. This report expresses discharge in cubic feet per second (cfs).

ELEVATION » The variation in the height of the earth's surface; the measure of the vertical distance from a known datum plane, which on most maps is mean sea level.

FILL » Material such as earth, clay, or crushed stone which is placed in an area and compacted to increase ground elevation.

FLASH FLOOD » A flood that crests in a short length of time and is often characterized by high velocity flow. It is often the result of heavy rainfall in a localized area.

FLOOD » An overflow of water onto lands not normally covered by water. The inundation is temporary and the land is adjacent to and inundated by overflow from a river, stream, ocean, lake, or other body of standing water.

FLOOD CREST » The maximum stage or elevation reached by waters of a flood at a given location. It may also be referred to as flood elevation.

FLOOD DAMAGE » Flood damages are significant adverse effects caused by any flood or temporary rise of stream flow or stage. The adverse effects include such things as accumulation of debris, damage to property, erosion, sedimentation, sewer, backup, traffic disruption, or other problems.

FLOOD DAMAGE STAGE » The stage or elevation in a stream or body of water at which damage becomes significant in the reach or area in which the elevation is measured. It is generally comparable to and commonly referred to as flood stage.

FLOOD FREQUENCY » An expression of how often a flood event of a given magnitude will, on the average, be equaled or exceeded. The word "frequency" often is omitted in discussing a flood event for the purpose of abbreviation. Examples follow:

10-year flood or 10-year frequency flood .. the flood which can be expected to be equaled or exceeded on an average of once in 10 years; and which would have a 10 percent chance of being equaled or exceeded in any given year.

50-year flood .. 2 percent chance in any given year.
100-year flood .. 1 percent chance in any given year.
500-year flood .. 2/10 percent chance in any given year.

FLOOD FRINGE » That portion of the flood plain that lies beyond the floodway and serves as a temporary storage area for flood waters during a flood. This section receives waters that are shallower and of lower velocities than those of the floodway.

FLOOD PEAK or PEAK DISCHARGE » The maximum instantaneous discharge of a flood at a given time. It usually occurs at or near the time of the flood crest.

FLOOD PLAIN, FLOOD PRONE AREA or FLOOD HAZARD AREA » Normally dry land adjoining a stream (or other body of water) that is susceptible to inundation by flood water.

FLOOD PLAIN ENCROACHMENT » Placement of fill or structures in the flood plain which may impede flood flow and cause backwater.

FLOOD PROOFING » A combination of structural provisions, changes or adjustments to properties and structures subject to flooding for the reduction or elimination of flood damages to properties, water and sanitary facilities, structures, and contents of buildings in a flood hazard area.

FLOOD ROUTING » Computation of the changes in streamflow as a flood moves downstream. The results provide hydrographs of discharge versus time at given points on the stream.

FLOOD STAGE » The stage or elevation at which overflow of the natural banks of a stream or body of water begins in the reach or area in which the elevation is measured. Also, see flood damage stage.

FREEFLOW » Unimpeded flow conditions. Flow considering no restrictions. Also the stage or elevation resulting from unobstructed conditions.

HEAD LOSS » The effect of natural or man-made obstructions such as accumulation of debris, bridge or culvert openings, buildings, or fill which limits the conveyance of water, causing a rise in upstream water surface elevation.

HYDROGRAPH » A plotted curve showing the rise and fall of flood discharge with respect to time at a specific point on a stream.

NATURAL STORAGE AREA » In this report, refers to depressional areas, marshes, lakes, and swamps that temporarily store a portion of the surface runoff.

ONE HUNDRED (100) YEAR FLOOD » The flood elevation that has a 1 percent chance of being equaled or exceeded in any given year. It is also known as a flood with a 100-year recurrence interval and the base flood elevation.

REACH » A specified length of stream or body of water.

RIPARIAN » Related to, living, or located on the area bordering a natural water body or watercourse.

RUNOFF » In this report, refers to the portion of precipitation (including snowmelt) that flows across the land surface and contributes to stream or flood flow.

STAGE DISCHARGE CURVE » A plotted curve showing the variation of discharge with water surface elevation at a point on a stream.

STAGE-STORAGE CURVE » A plotted curve showing the accumulated storage available for floodwater upstream from a point on a stream versus the stage at that point.

VALLEY CROSS SECTION » The relationship of the elevation of the ground to the horizontal distance across a valley perpendicular to the direction of flow.

WATERSHED » A drainage basin or area which collects and transmits runoff to the outlet of the drain.

WATERSHED BOUNDARY or DRAINAGE BOUNDARY » The divide separating one watershed from another.

WATER SURFACE PROFILE » The relationship of water surface elevation to stream channel elevation at points along a stream, generally drawn to show the water surface elevation for the peak of a specific food, but may be prepared for conditions at any given time.

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TECHNICAL APPENDICES

APPENDIX A - Flood Hazard Maps

APPENDIX B - Flood Profiles

APPENDIX C - Typical Cross Sections

APPENDIX D - Investigation and Analysis

APPENDIX E - Discharge Frequency Data

APPENDIX F - Water Surface Elevations and Frequency Data

APPENDIX G - Existing Works of Improvement

APPENDIX H - Soils

APPENDIX I - Floodways

APPENDIX J - Existing Bridges and Culverts

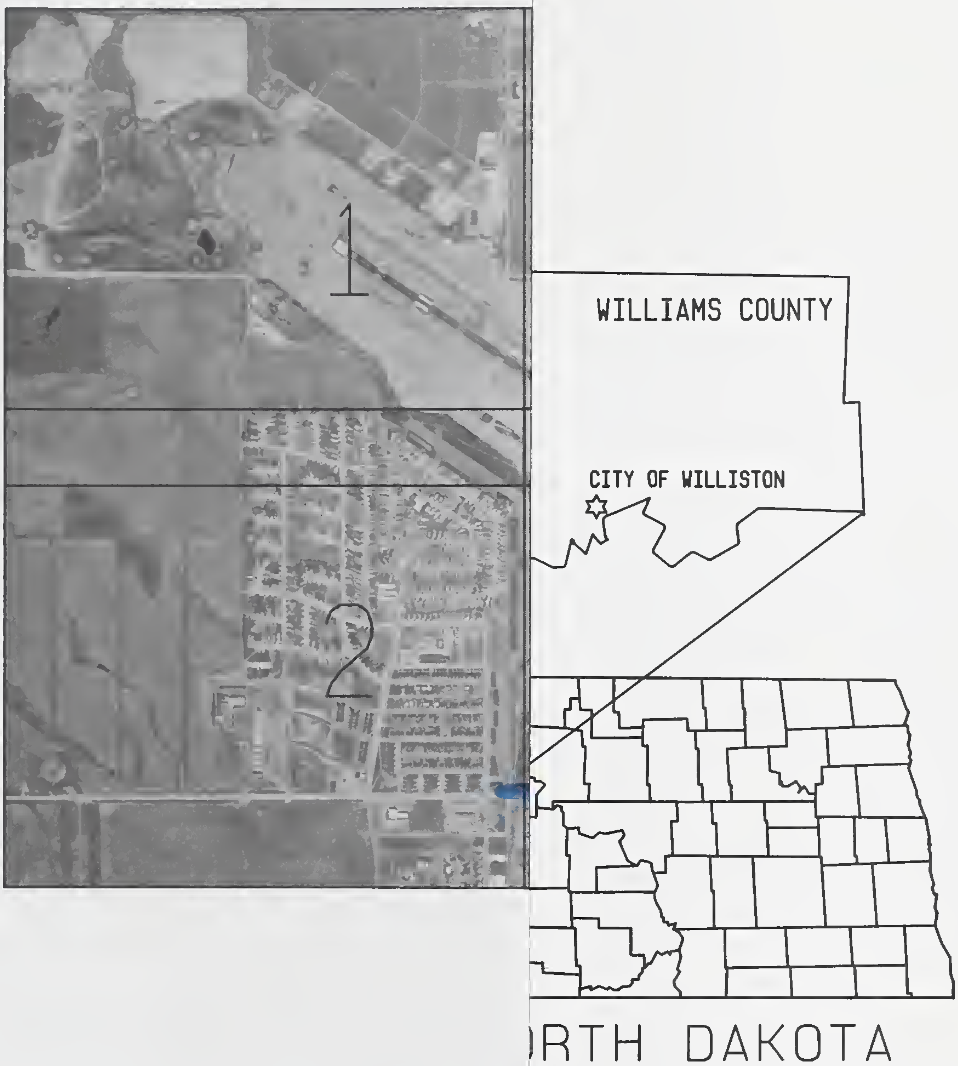
APPENDIX K - Elevation Reference Marks

FLOOD HAZARD MAPS

The following photomaps show the flood hazard area for the 100- and 500-year flood events.

It is acknowledged there may be some areas within the delineated flood plain boundaries above the flood elevations. These areas would be flood-free islands during the flood. Due to time and monetary restrictions, limitations of the map scale and/or lack of detailed topographic data, it was impossible to define each area.

Specific site elevations should be field surveyed to establish flood potential. This procedure requires the use of land surveying techniques performed by a licensed land surveyor or registered professional engineer. A field survey uses benchmarks to align the flood level with reference to the ground at the structure, and therefore, determines the height of water at or upon the structure for a given flood. Surveyed elevations are compared to flood plain elevations at cross sections or interpolated between cross sections by using channel mile distances.



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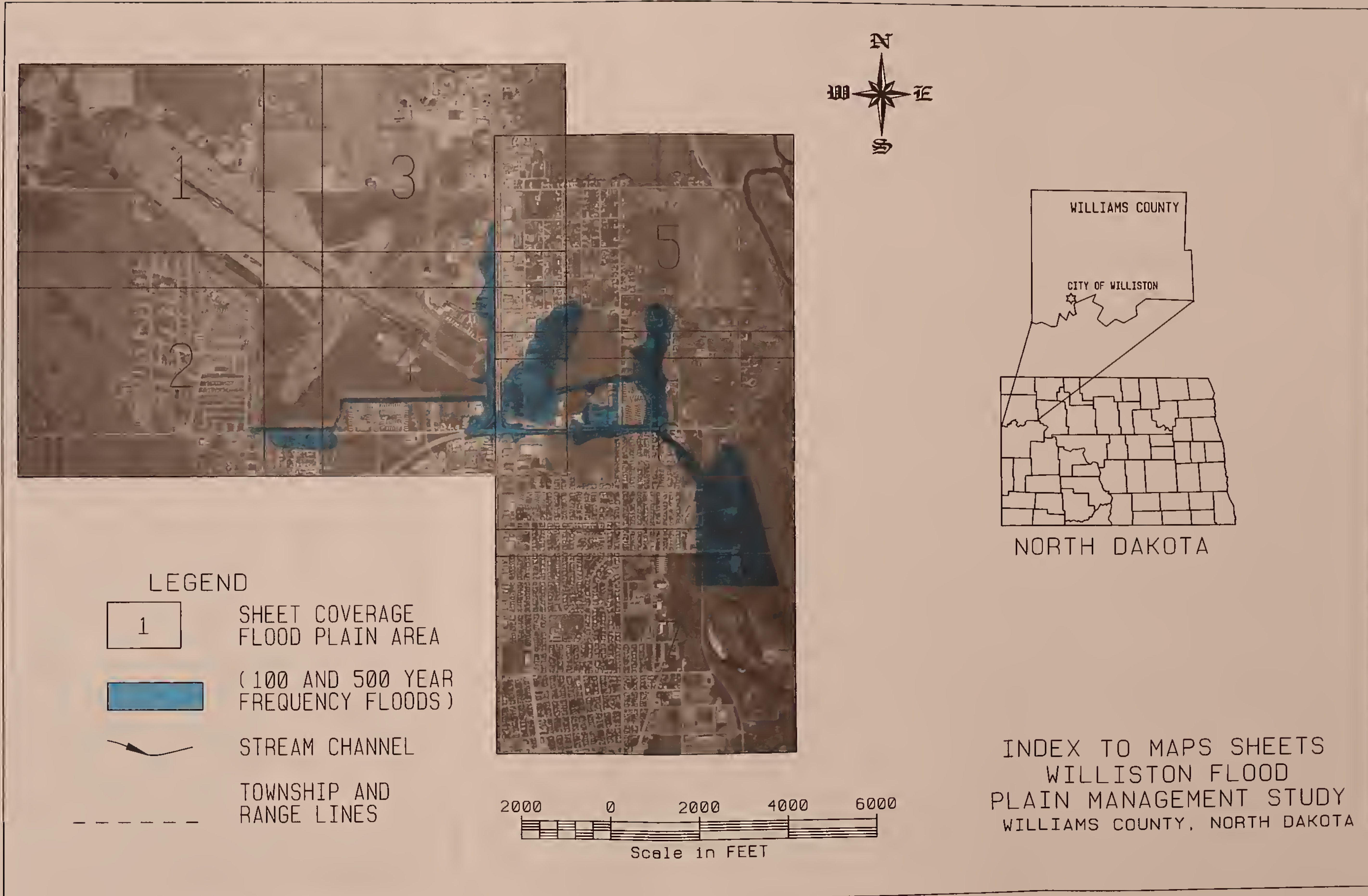
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WILLIAMS COUNTY
CITY OF WILLISTON
NORTH DAKOTA
LEGEND
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SHEET COVERAGE
FLOOD PLAIN AREA
(100 AND 500 YEAR
FREQUENCY FLOODS)
STREAM CHANNEL
TOWNSHIP AND
RANGE LINES
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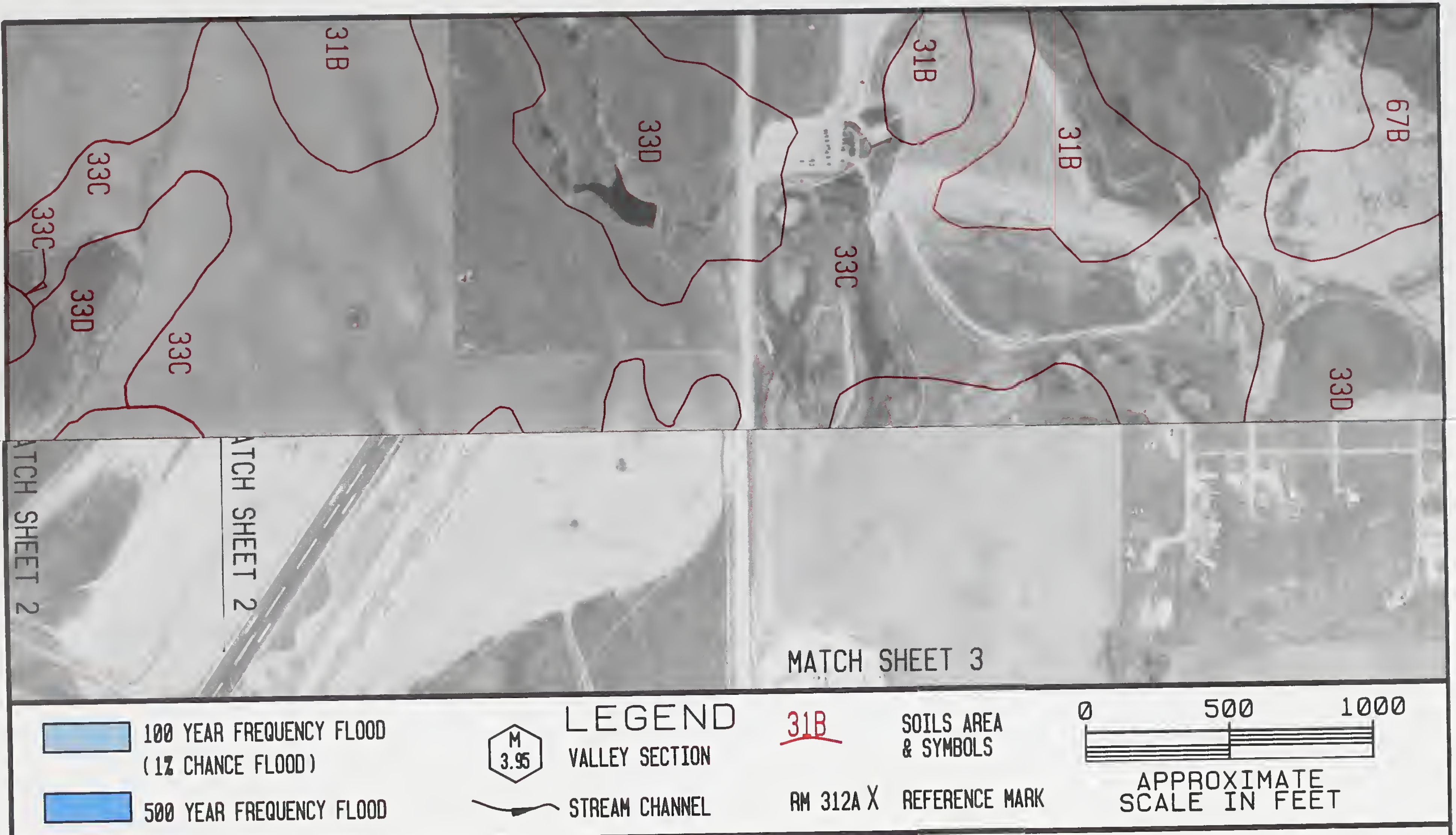
WILLISTON FLOOD
PLAIN MANAGEMENT STUDY
WILLIAMS COUNTY, NORTH DAKOTA



U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
FLOOD PLAIN MANAGEMENT STUDY
WILLIAMS COUNTY,
NORTH DAKOTA

FLOOD HAZARD AREA

WILLISTON FLOOD PLAIN MANAGEMENT STUDY

SHT 1 OF 7

LEGEND

100 YEAR FREQUENCY FLOOD (1% CHANCE FLOOD)	M 3.95 VALLEY SECTION	31B SOILS AREA & SYMBOLS	0 500 1000 APPROXIMATE SCALE IN FEET
500 YEAR FREQUENCY FLOOD	STREAM CHANNEL	RM 312A X REFERENCE MARK	

SHT 1 OF 7

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
FLOOD PLAIN MANAGEMENT STUDY
WILLIAMS COUNTY,
NORTH DAKOTA

FLOOD HAZARD AREA

WILLISTON FLOOD PLAIN MANAGEMENT STUDY

LEGEND

(light blue)	100 YEAR FREQUENCY FLOOD (1% CHANCE FLOOD)
(blue)	500 YEAR FREQUENCY FLOOD
M 3.95	VALLEY SECTION
(line)	STREAM CHANNEL
31B	SOILS AREA & SYMBOLS
RM 312A X	REFERENCE MARK

0 500 1000
APPROXIMATE SCALE IN FEET

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
FLOOD PLAIN MANAGEMENT STUDY
WILLIAMS COUNTY,
NORTH DAKOTA

FLOOD HAZARD AREA

WILLISTON FLOOD PLAIN MANAGEMENT STUDY

SHT 2 OF 7

LEGEND

100 YEAR FREQUENCY FLOOD (1% CHANCE FLOOD)	(M 3.95) VALLEY SECTION	31B SOILS AREA & SYMBOLS	0 500 1000 APPROXIMATE SCALE IN FEET
500 YEAR FREQUENCY FLOOD	STREAM CHANNEL	RM 312A X REFERENCE MARK	

SHT 2 OF 7

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
FLOOD PLAIN MANAGEMENT STUDY
WILLIAMS COUNTY,
NORTH DAKOTA

FLOOD HAZARD AREA

WILLISTON FLOOD PLAIN MANAGEMENT STUDY

LEGEND

100 YEAR FREQUENCY FLOOD (1% CHANCE FLOOD)

500 YEAR FREQUENCY FLOOD

M 3.95 VALLEY SECTION

STREAM CHANNEL

31B SOILS AREA & SYMBOLS

RM 312A X REFERENCE MARK

0 500 1000
APPROXIMATE SCALE IN FEET

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
FLOOD PLAIN MANAGEMENT STUDY
WILLIAMS COUNTY,
NORTH DAKOTA

FLOOD HAZARD AREA

WILLISTON FLOOD PLAIN MANAGEMENT STUDY

SHT 3 OF 7

LEGEND

100 YEAR FREQUENCY FLOOD (1% CHANCE FLOOD)

500 YEAR FREQUENCY FLOOD

M 3.95 VALLEY SECTION

STREAM CHANNEL

31B SOILS AREA & SYMBOLS

RM 312A X REFERENCE MARK

0 500 1000

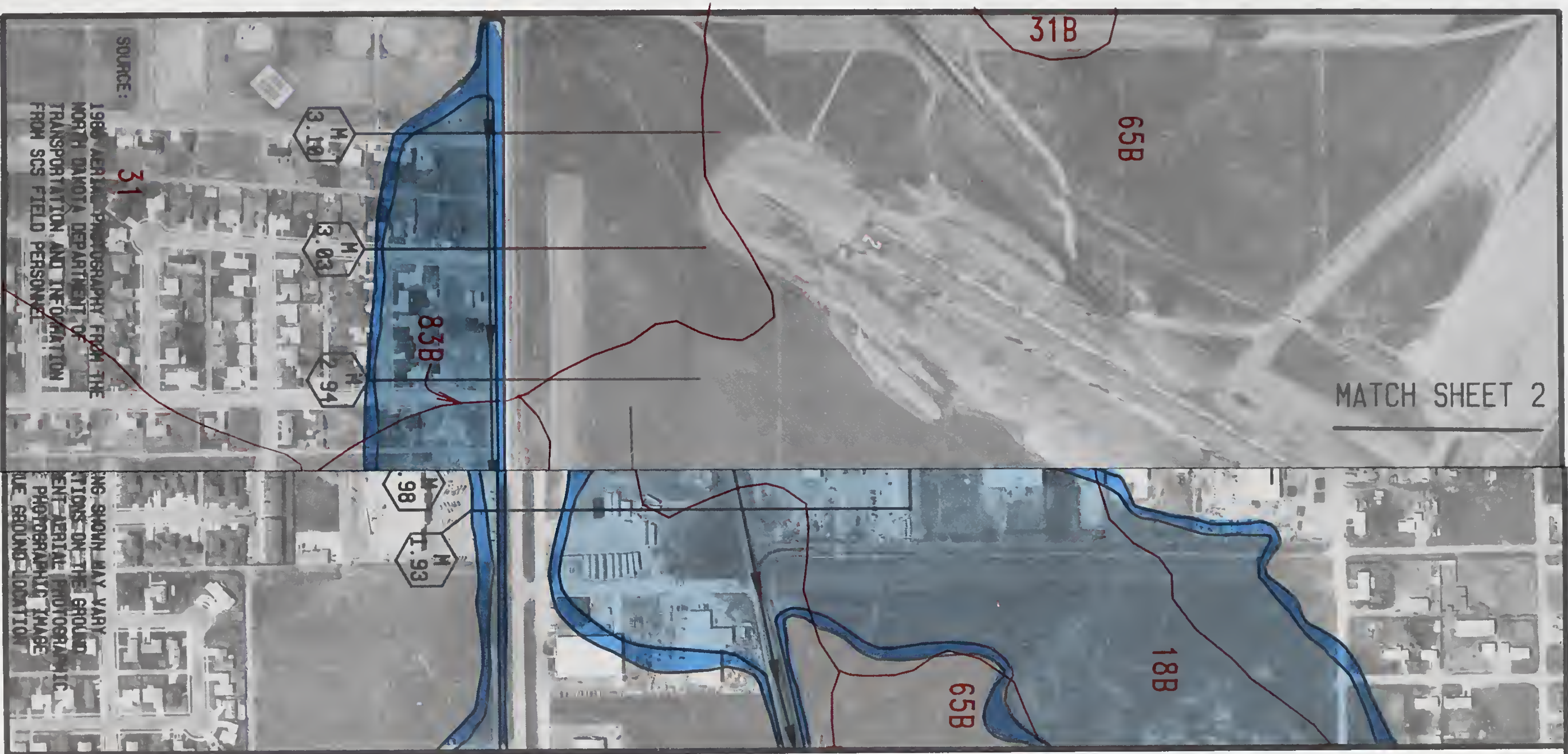
APPROXIMATE SCALE IN FEET

SHT 3 OF 7

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
FLOOD PLAIN MANAGEMENT STUDY
WILLIAMS COUNTY,
NORTH DAKOTA

FLOOD HAZARD AREA

WILLISTON FLOOD PLAIN MANAGEMENT STUDY



LEGEND

100 YEAR FREQUENCY FLOOD (1% CHANCE FLOOD)	
500 YEAR FREQUENCY FLOOD	
M 3.95	VALLEY SECTION
(symbol)	STREAM CHANNEL
31B	SOILS AREA & SYMBOLS
RM 312A X	REFERENCE MARK

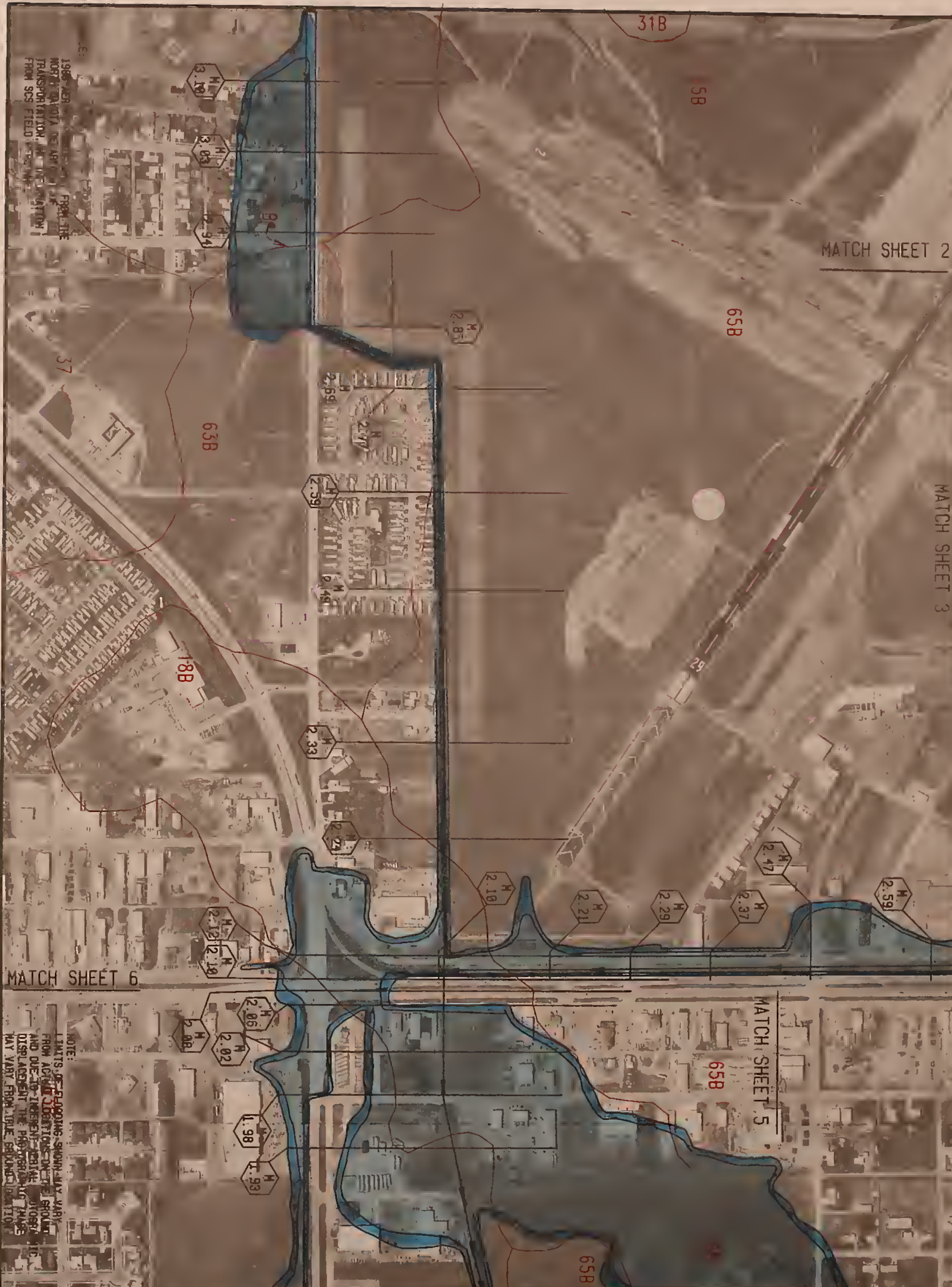
0 500 1000
APPROXIMATE SCALE IN FEET

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
FLOOD PLAIN MANAGEMENT STUDY
WILLIAMS COUNTY,
NORTH DAKOTA

FLOOD HAZARD AREA

WILLISTON FLOOD PLAIN MANAGEMENT STUDY

SHT 4 OF 7



LEGEND

100 YEAR FREQUENCY FLOOD (1% CHANCE FLOOD)

500 YEAR FREQUENCY FLOOD

M 3.95 VALLEY SECTION

STREAM CHANNEL

31B SOILS AREA & SYMBOLS

RM 312A X REFERENCE MARK

0 500 1000

APPROXIMATE SCALE IN FEET

SHT 4 OF 7

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
FLOOD PLAIN MANAGEMENT STUDY
WILLIAMS COUNTY,
NORTH DAKOTA

FLOOD HAZARD AREA

WILLISTON FLOOD PLAIN MANAGEMENT STUDY

LEGEND

100 YEAR FREQUENCY FLOOD (1% CHANCE FLOOD)

500 YEAR FREQUENCY FLOOD

M 3.95 VALLEY SECTION

STREAM CHANNEL

31B SOILS AREA & SYMBOLS

RM 312A X REFERENCE MARK

0 500 1000

APPROXIMATE SCALE IN FEET

SHT 5 OF 7

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
FLOOD PLAIN MANAGEMENT STUDY
WILLIAMS COUNTY,
NORTH DAKOTA

FLOOD HAZARD AREA

WILLISTON FLOOD PLAIN MANAGEMENT STUDY

LEGEND

100 YEAR FREQUENCY FLOOD (1% CHANCE FLOOD)	M 3.95	VALLEY SECTION	31B	SOILS AREA & SYMBOLS	0 500 1000
500 YEAR FREQUENCY FLOOD		STREAM CHANNEL	RM 312A X	REFERENCE MARK	APPROXIMATE SCALE IN FEET

SHT 5 OF 7

U.S. DEPARTMENT OF AGRICULTURE
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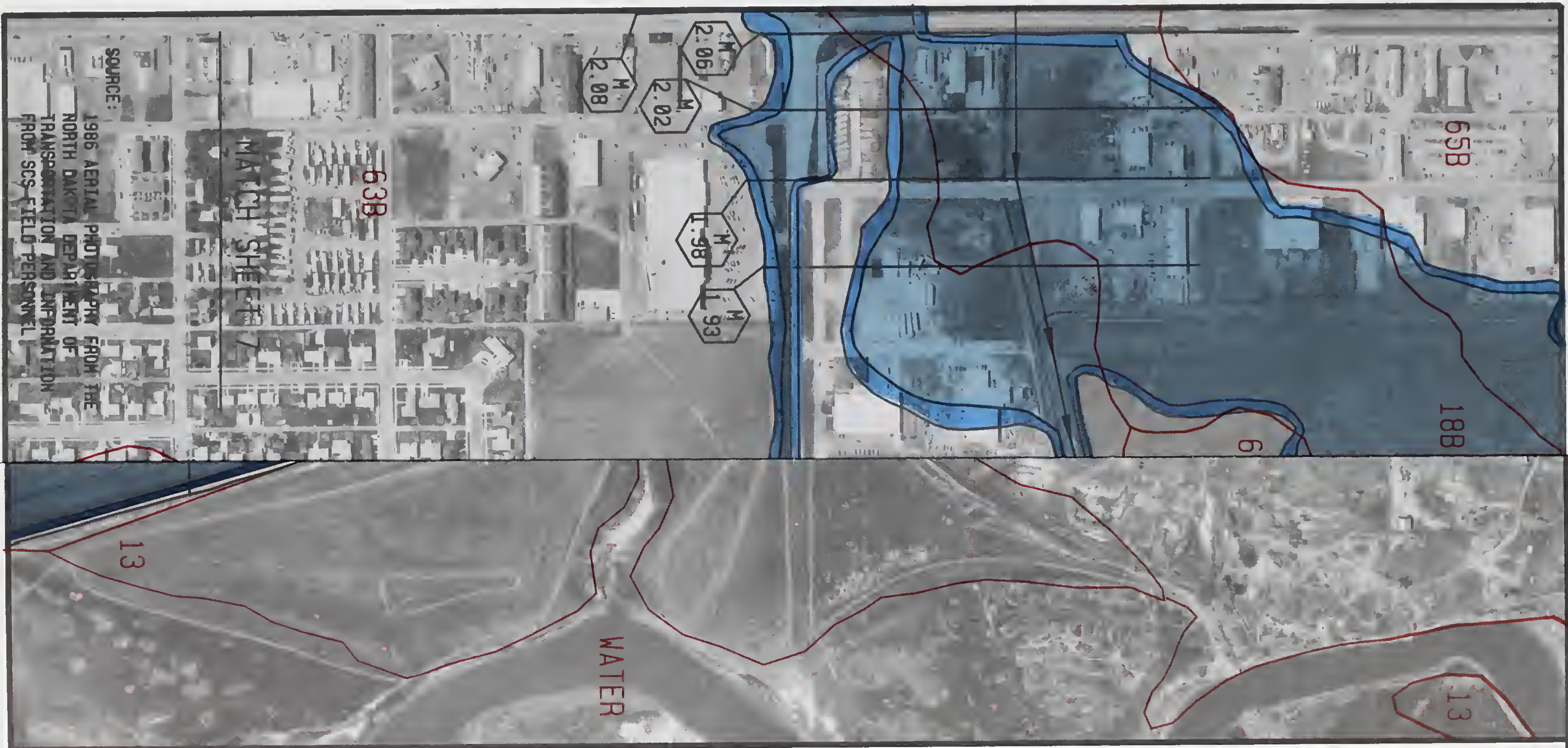
FLOOD PLAIN MANAGEMENT STUDY
WILLIAMS COUNTY,
NORTH DAKOTA

FLOOD HAZARD AREA

WILLISTON FLOOD PLAIN MANAGEMENT STUDY



LEGEND

100 YEAR FREQUENCY FLOOD (1% CHANCE FLOOD)

500 YEAR FREQUENCY FLOOD

M 3.95 VALLEY SECTION

STREAM CHANNEL

31B SOILS AREA & SYMBOLS

RM 312A X REFERENCE MARK

0 500 1000
APPROXIMATE SCALE IN FEET

U.S. DEPARTMENT OF AGRICULTURE
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FLOOD PLAIN MANAGEMENT STUDY
WILLIAMS COUNTY,
NORTH DAKOTA

FLOOD HAZARD AREA

WILLISTON FLOOD PLAIN MANAGEMENT STUDY

SHT 6 OF 7

LEGEND

100 YEAR FREQUENCY FLOOD (1% CHANCE FLOOD)	M 3.95 VALLEY SECTION	31B SOILS AREA & SYMBOLS	0 500 1000 APPROXIMATE SCALE IN FEET
500 YEAR FREQUENCY FLOOD	STREAM CHANNEL	RM 312A X REFERENCE MARK	

SHT 6 OF 7

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
FLOOD PLAIN MANAGEMENT STUDY
WILLIAMS COUNTY,
NORTH DAKOTA

FLOOD HAZARD AREA

WILLISTON FLOOD PLAIN MANAGEMENT STUDY

LEGEND

- 100 YEAR FREQUENCY FLOOD (1% CHANCE FLOOD)
- 500 YEAR FREQUENCY FLOOD
- M 3.95 — VALLEY SECTION
- STREAM CHANNEL
- 31B — SOILS AREA & SYMBOLS
- RM 312A X — REFERENCE MARK

0 500 1000
APPROXIMATE SCALE IN FEET

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
FLOOD PLAIN MANAGEMENT STUDY
WILLIAMS COUNTY,
NORTH DAKOTA

FLOOD HAZARD AREA

WILLISTON FLOOD PLAIN MANAGEMENT STUDY

LEGEND

100 YEAR FREQUENCY FLOOD (1% CHANCE FLOOD)	M 3.95 VALLEY SECTION	31B SOILS AREA & SYMBOLS	0 500 1000
500 YEAR FREQUENCY FLOOD	STREAM CHANNEL	RM 312A X REFERENCE MARK	APPROXIMATE SCALE IN FEET

SHT 7 OF 7

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
FLOOD PLAIN MANAGEMENT STUDY
WILLIAMS COUNTY,
NORTH DAKOTA

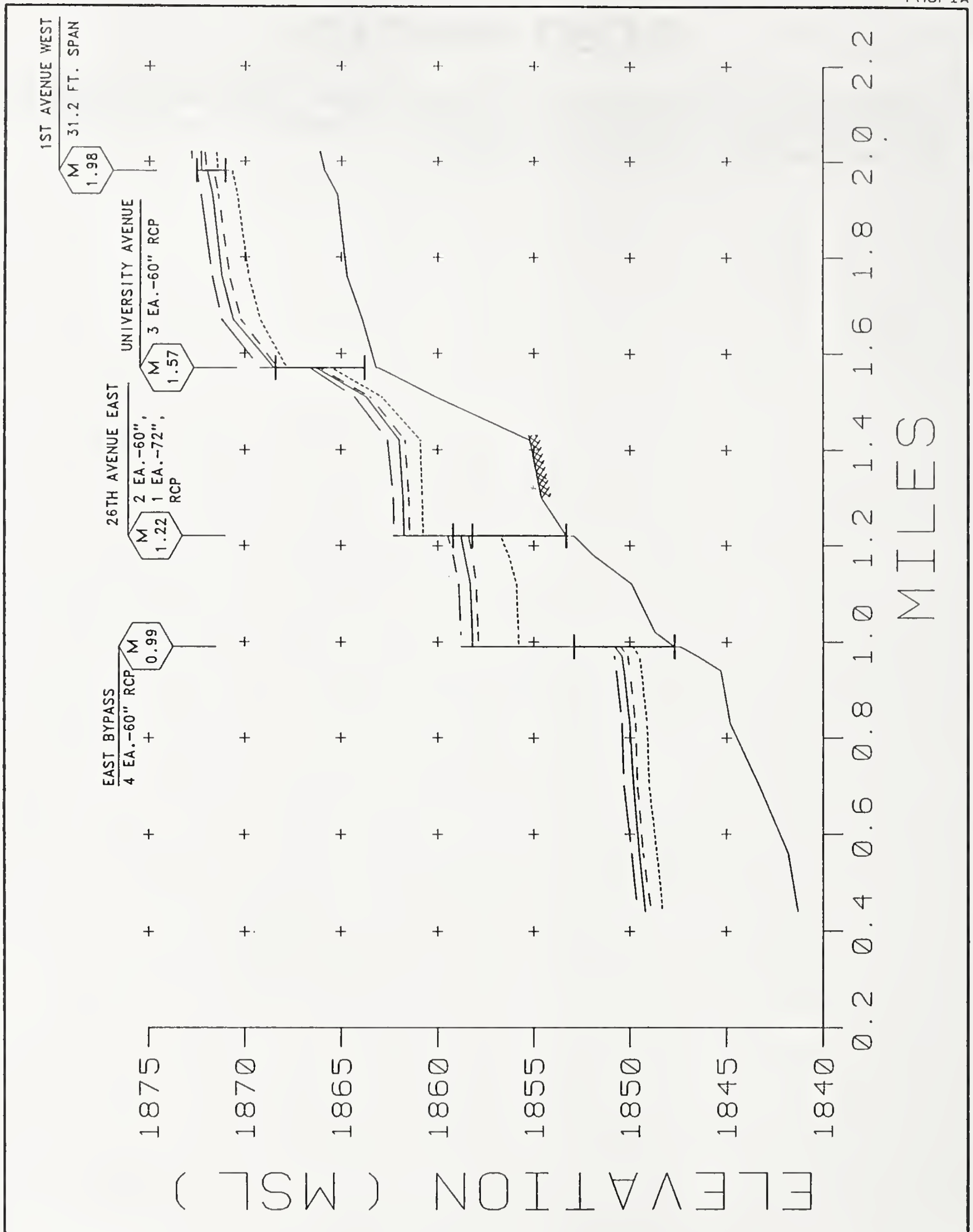
FLOOD HAZARD AREA

WILLISTON FLOOD PLAIN MANAGEMENT STUDY

FLOOD PROFILES

NOTE: Scales used for flood profiles are difficult to read. Profiles should be used for general locations and elevations. For closer interpretations, see Appendix F, Water Surface Elevations and Frequency Data.

PROF1A

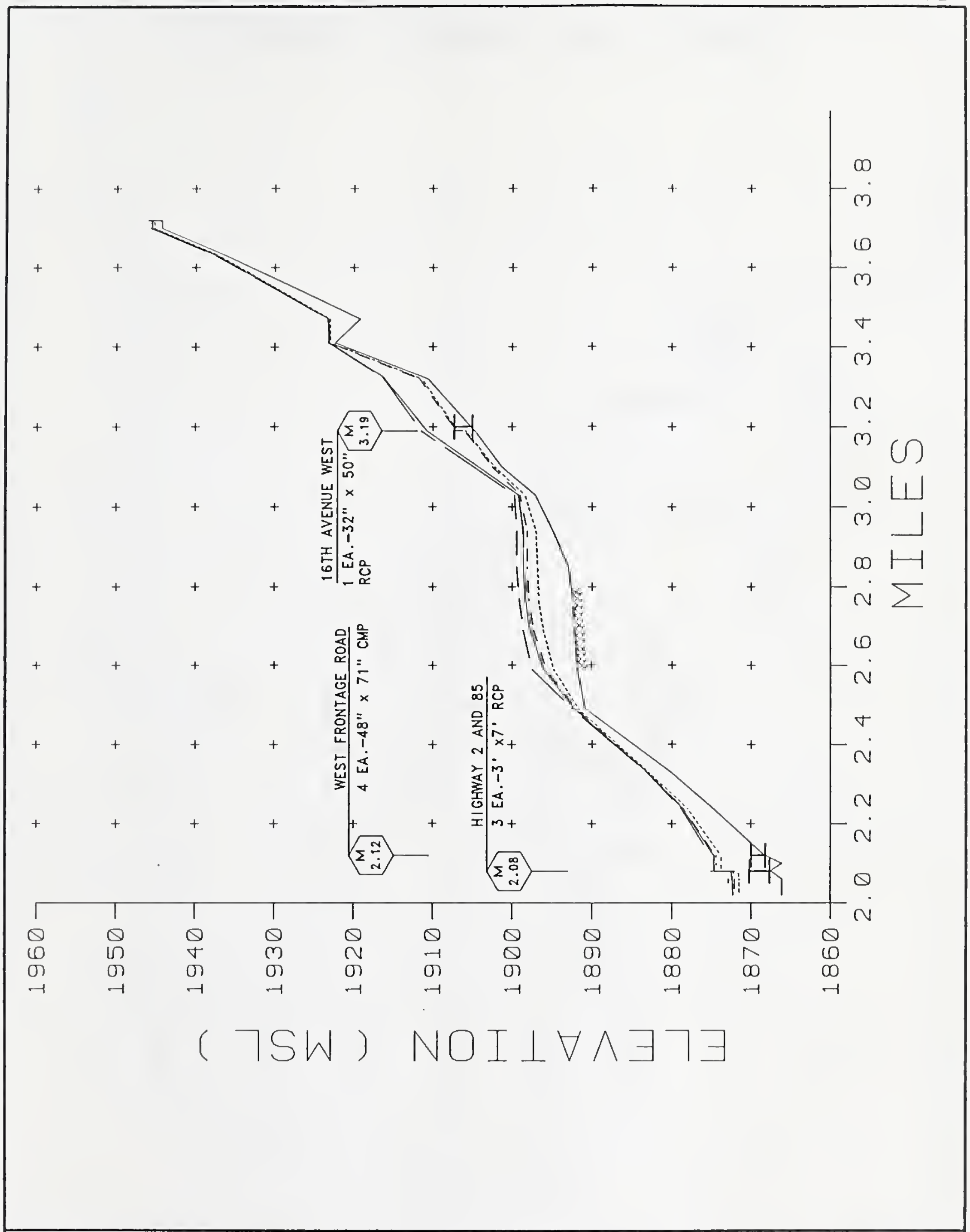


LEGEND:

- 500-YEAR FLOOD
- 100-YEAR FLOOD
- 50-YEAR FLOOD
- 10-YEAR FLOOD
- STREAM BED
- M 1.57 CROSS SECTION LOCATION
- CULVERT (INVERT): TOP, INVERT
- BRIDGE: DECK, LOW BEAM

SHEET 1 OF 3	U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE FLOOD PLAIN MANAGEMENT STUDY WILLIAMS COUNTY, NORTH DAKOTA	PROFILES CHANNEL MILES 0.44 TO 2.00 MAIN TRIBUTARY

PROF2A



LEGEND:

500-YEAR FLOOD	10-YEAR FLOOD	CULVERT (INLET): TOP / INVERT
100-YEAR FLOOD	STREAM BED	
50-YEAR FLOOD		BRIDGE: DECK / LOW BEAM

M 3.19 CROSS SECTION LOCATION

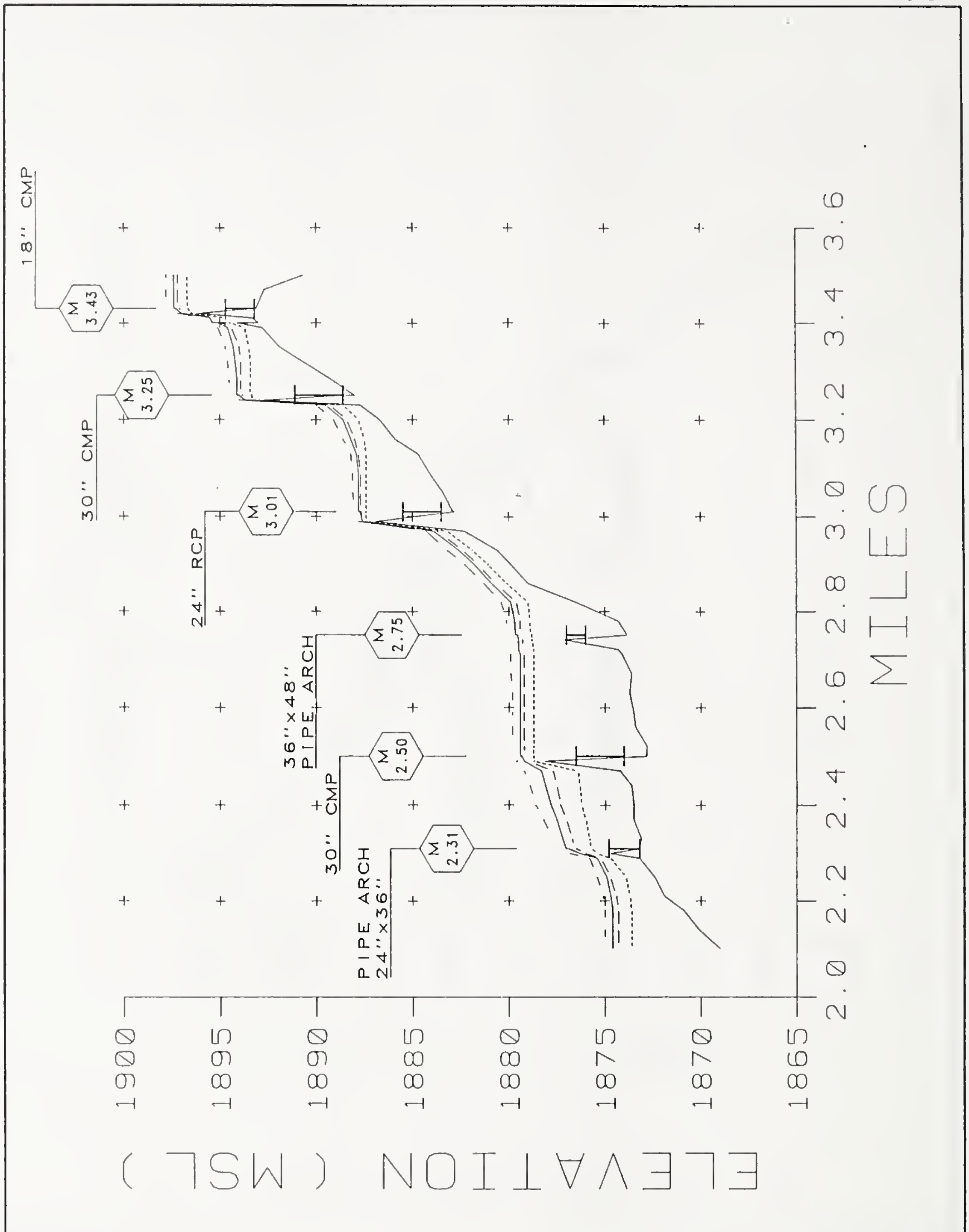
SHEET 2 OF 3

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
FLOOD PLAIN MANAGEMENT STUDY
WILLIAMS COUNTY,
NORTH DAKOTA

PROFILES
CHANNEL MILES 2.00 TO 3.70

MAIN TRIBUTARY

PROF3A



LEGEND:

- 500-YEAR FLOOD
- 100-YEAR FLOOD
- 50-YEAR FLOOD
- 10-YEAR FLOOD
- STREAM BED
- M 2.00 CROSS SECTION LOCATION
- CULVERT (INLET) TOP / INVERT

SHEET 3 OF 3 — U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE FLOOD PLAIN MANAGEMENT STUDY WILLIAMS COUNTY, NORTH DAKOTA	PROFILES CHANNEL MILES 2.10 TO 3.50 HIGHWAY 2 AND 85 DITCH

TYPICAL CROSS SECTIONS

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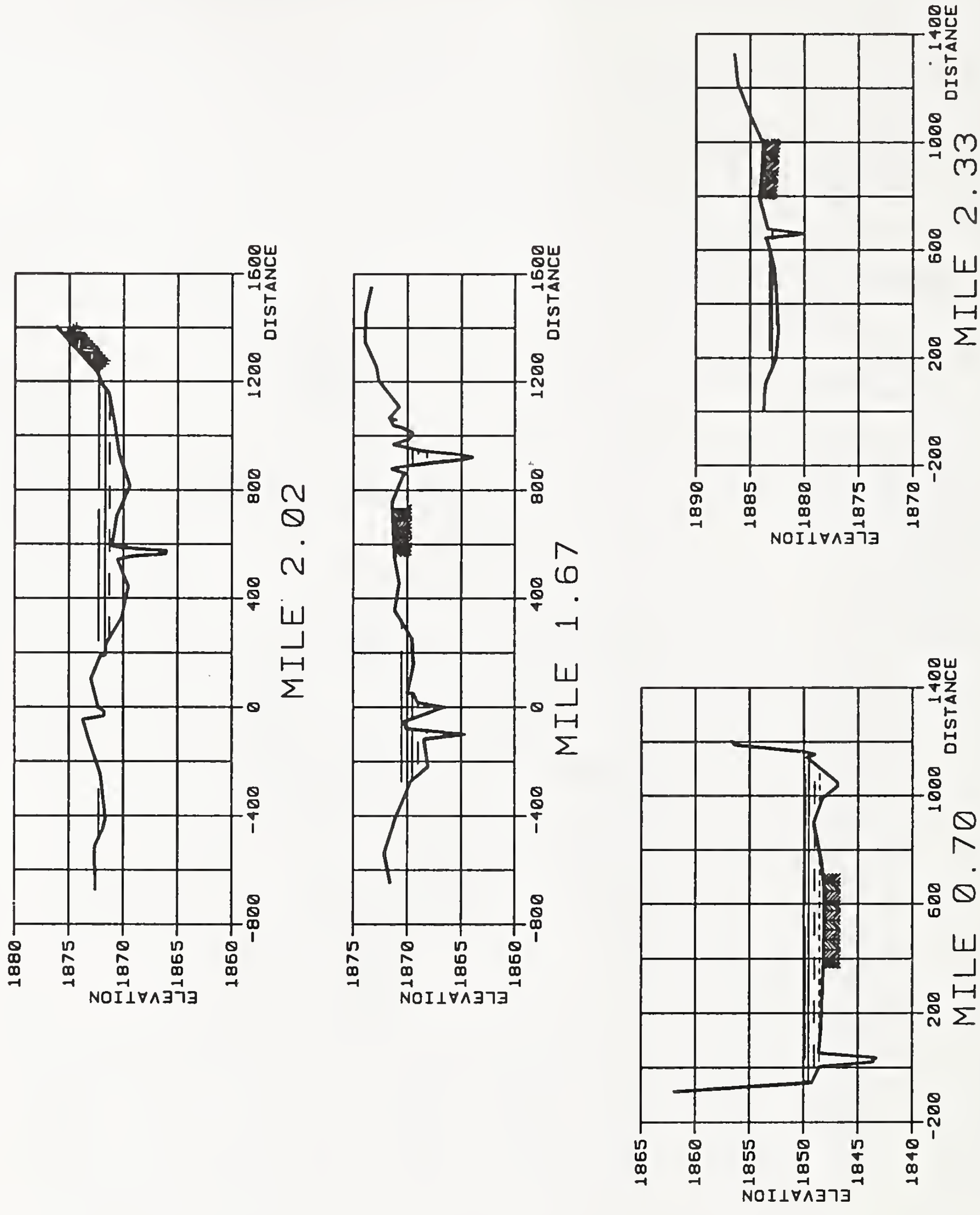


LEGEND:

500-YEAR FLOOD

100-YEAR FLOOD

50-YEAR FLOOD

10-YEAR FLOOD

GROUND LINE

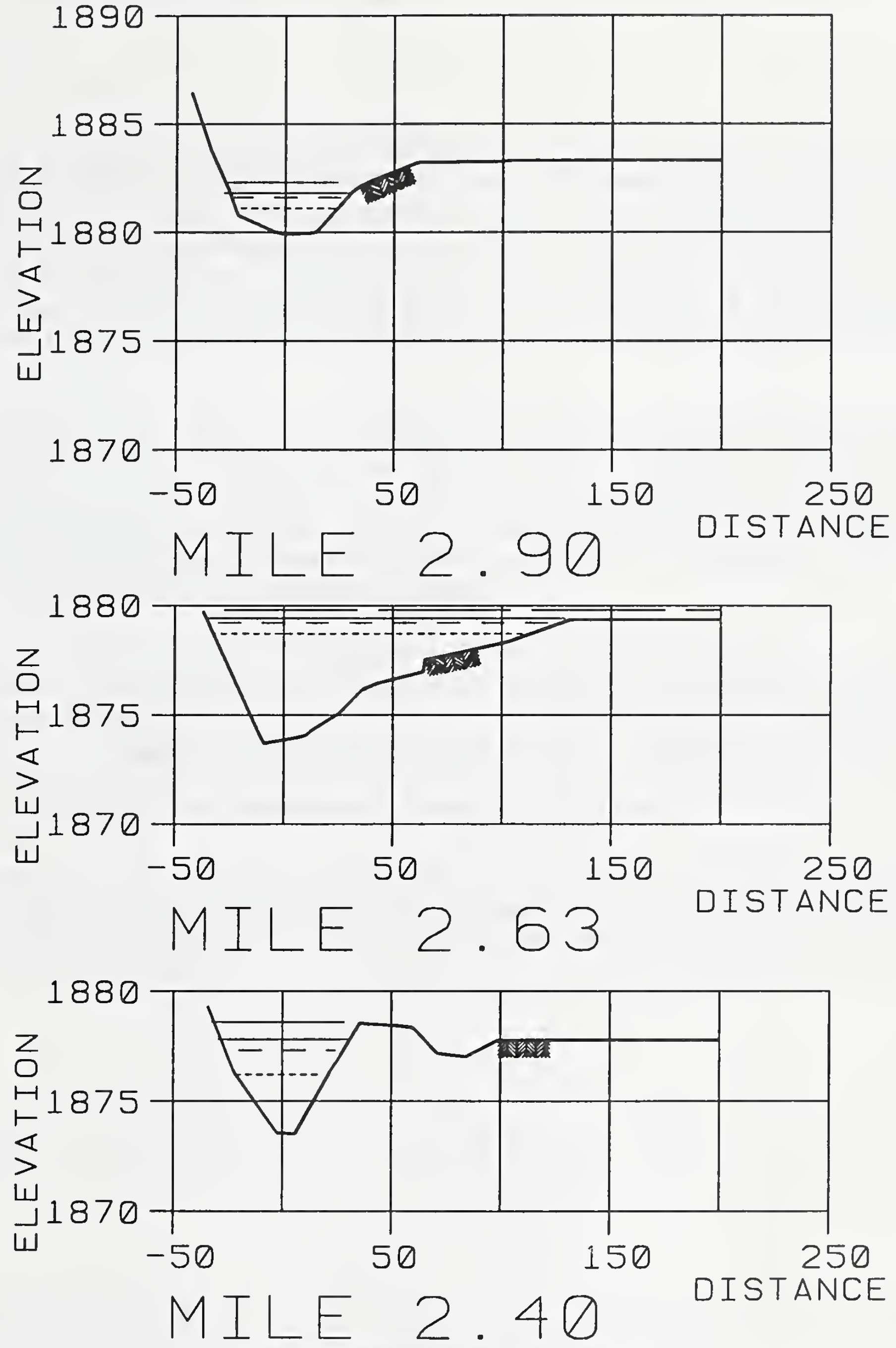
SHEET 1 OF 2

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
FLOOD PLAIN MANAGEMENT STUDY
CITY OF WILLISTON
WILLIAMS COUNTY, NORTH DAKOTA

TYPICAL CROSS SECTIONS

MAIN TRIBUTARY

xxx



LEGEND:

- 500-YEAR FLOOD
- 100-YEAR FLOOD
- 50-YEAR FLOOD
- 10-YEAR FLOOD
- GROUND LINE

SHEET 2 OF 2

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
FLOOD PLAIN MANAGEMENT STUDY
CITY OF WILLISTON
WILLIAMS COUNTY, NORTH DAKOTA

TYPICAL CROSS SECTIONS

U.S. HIGHWAY 2 & 85 DITCH

INVESTIGATION AND ANALYSIS

SURVEYS

A bench mark circuit was established throughout the study area using existing U.S. Geological Survey (USGS) Coast and Geodetic Bench Marks. Elevation reference marks are located throughout the study area. These reference marks can be used to determine flood elevations as indicated in this flood hazard analyses. Detailed locations, descriptions, and elevations for a limited number of reference marks can be obtained in Appendix I. The City of Williston Engineering Department has numerous other elevation reference marks located throughout the city.

Third order levels were used as the basis of accuracy in field surveys. Channel and valley cross sections, covering the Main Tributary distance of 3.72 miles and the U.S. Highway 2 & 85 distance of 2.40 miles, were field surveyed and analyzed. Aerial photography was used for compilation of the photomaps. The 100-year and 500-year flood lines and cross sections are located on the photomaps in the Flood Hazard Maps section.

The geometry of all bridges and culverts was measured for use in the water surface profiles. Photographs of bridges and culverts on the Main Tributary are shown, with water surface elevations for the 100- and 500-year frequency events, in Appendix H. A typical (representative) photograph is shown for the U.S. Highway 2 & 85 ditch at the mile 2.63 road approach. Sizes and shapes of culverts are also shown on the flood profiles in Appendix B.

Flood plain lines for the 100- and 500-year flood events shown on the Flood Hazard Maps were developed using survey equipment, supplemented with existing topographic maps supplied by the city of Williston, with calculated water surface elevations at cross sections.

HYDROLOGY AND HYDRAULICS

Peak discharges vary throughout the study area based on the size of the contributing drainage area. Total drainage area at the lower end of the study (Mile 0.00) is approximately 5.82 square miles (3725 acres). Discharges are based on a TR-20 hydrologic model (reference 4), using procedures outlined by the Soil Conservation Service (reference 10). The Watershed Schematic is shown on page D-3. Existing features, such as ponds and diversions, were incorporated with appropriate stage discharge and stage-storage curves for flood routing to develop discharge hydrographs.

Water surface elevations for the 10-, 50-, 100-, and 500-year flood events were computed using the Soil Conservation Service's WSP2 computer program (reference 14), which performs subcritical backwater computations by a modified step method. The program includes head loss computations at restrictive sections such as roadway bridge openings or culverts, using the U.S. Bureau of Public Roads Method.

Roughness coefficients (Manning's "n") used in the hydraulic computations were chosen using Soil Conservation Service and Federal Highway Department guidelines (reference 9). The channel values averaged 0.035 while flood plain values averaged 0.050, with flood plain values reduced to 0.035 when flow depths exceeded 3 feet. Roughness values can vary considerably depending on the time of year, foliage, and extent of improvements such as channel maintenance in any particular reach. Values chosen represent a composite estimate at the time of study.

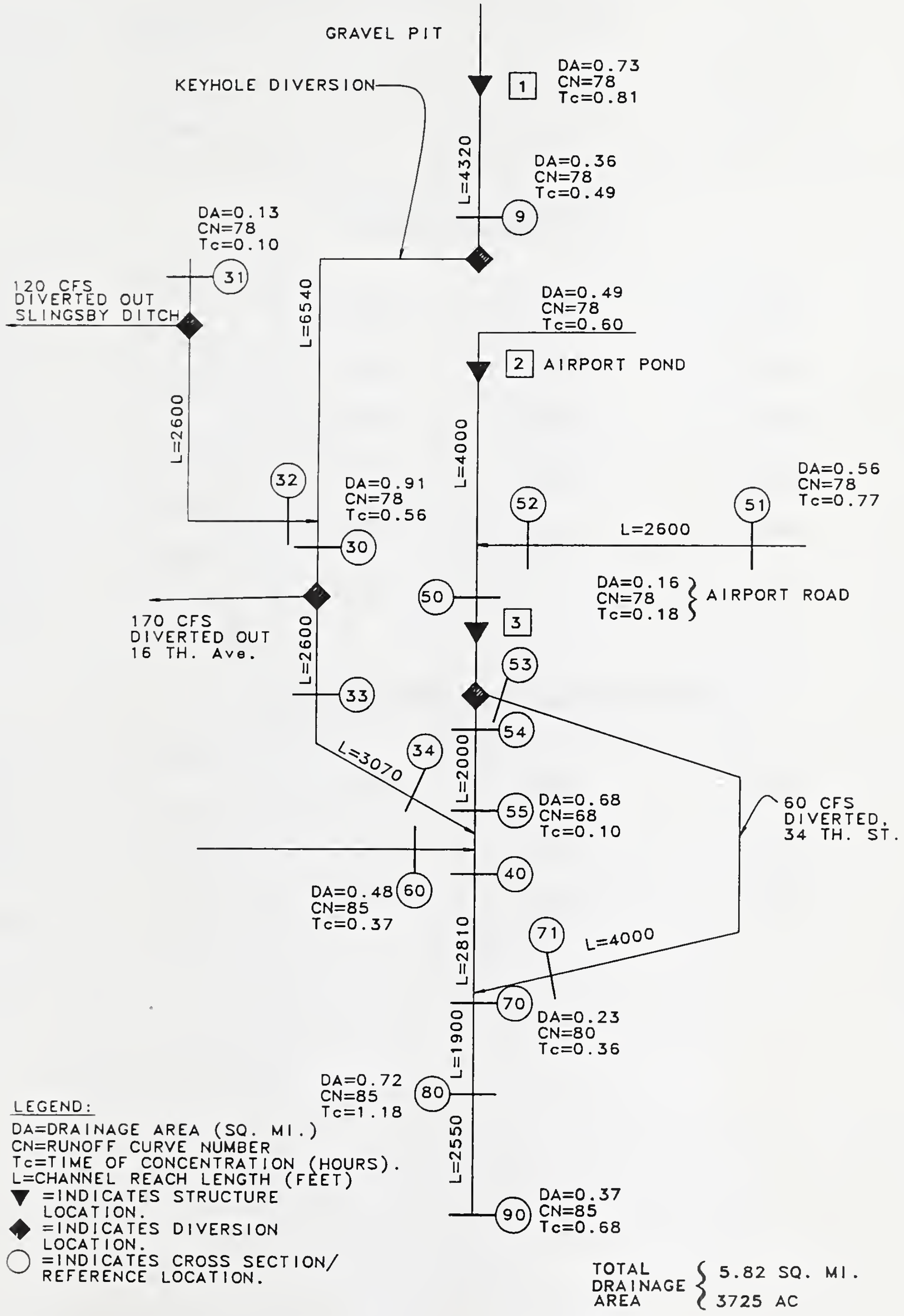
The starting elevations at the mouth of the tributary (mile 0.00) were obtained from comparing estimated energy gradients and written correspondence with the U.S. Army Corps of Engineers.

The hydraulic analyses for this study were based on freeflow conditions. The flow elevations shown on the profiles are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail.

The 100-year flood was computed to emphasize the effect of constrictions (bridge openings) on flooding and provide a basis for analyzing future improvements. The 100-year flood also serves as the base flood which U.S. Housing and Urban Development (HUD) and others consider as a minimum for flood insurance studies (references 1,7,8,12). Resulting elevations at selected cross sections are displayed in Appendix F.

It should be noted and emphasized, however, that the unobstructed or freeflow elevations are often less than historical elevations due to the susceptibility to ice and debris blockages. Flat topography can cause large areas to be flooded with relatively small increases in stages. Future projections indicate the expected encroachment at locations within the study area may also affect the flood stages slightly.

The study does not attempt to define overland, internal drainage within the city. Storm sewers are assumed to be adequate for the period of design, generally 10-year frequency events, but they are inadequate for less frequent events like the 100-year. Stormwater backup, because of surface ditches flowing full and similar internal drainage problems, are beyond the scope of this study. Relatively minor topographic changes, such as grading of back yards, can also cause isolated flood damage areas.



WILLISTON FPMS
WATERSHED SCHEMATIC

U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

	Date		Date
Approved		Designed J.E.N.	4/92
Title		Drawn J.R.D.	4/92
....		Traced	
Title		Checked T.J.C.	4/92

DISCHARGE - FREQUENCY DATA
EXISTING CONDITIONS

BETWEEN CHANNEL MILES	DRAINAGE AREA (ACRES)[1]	500-YEAR FREQUENCY Q (CFS)	100-YEAR FREQUENCY Q (CFS)	50-YEAR FREQUENCY Q (CFS)	10-YEAR FREQUENCY Q (CFS)
MAIN TRIBUTARY					
0.44	3,725				
		1,830	1,180	900	480
1.22	3,725				
		1,740	1,140	870	470
1.57	3,490				
		1,370	870	650	330
1.93	3,025				
		1,210	750	560	280
2.10	2,880				
		570	310	180	45
3.19	1,365				
		10	0	0	0
3.72	85				
U.S. HIGHWAY 2 & 85 DITCH					
2.10	1,210				
		660	380	260	90
2.47	1,210				
		350	200	140	30
2.50	770				
		410	260	200	90
2.98	770				

[1] Total Drainage, including controlled storage areas and diverted acres.

WATER SURFACE ELEVATIONS IN FEET (MSL)
SELECTED FREQUENCIES
EXISTING CONDITIONS

CHANNEL MILES [1]	500-YEAR FREQUENCY	100-YEAR FREQUENCY	50-YEAR FREQUENCY	10-YEAR FREQUENCY
		MAIN TRIBUTARY		
0.44	1849.0	1848.6	1848.3	1847.7
0.56	1849.4	1848.9	1848.7	1848.0
0.70	1849.7	1849.3	1849.0	1848.5
0.83	1849.8	1849.4	1849.1	1848.6
0.94	1850.1	1849.6	1849.4	1848.8
0.97	1850.2	1849.8	1849.5	1848.9
0.99	1850.6	1850.1	1849.9	1849.4
0.99	1858.0	1857.3	1855.9	1852.3
1.02	1858.0	1857.3	1855.9	1852.3
1.12	1858.1	1857.4	1856.0	1853.2
1.18	1858.3	1857.6	1856.4	1854.6
1.22	1858.5	1857.8	1856.8	1855.5
1.22	1861.5	1861.1	1860.7	1859.1
1.30	1861.6	1861.1	1860.8	1859.1
1.42	1861.8	1861.2	1860.9	1859.4
1.51	1863.6	1863.3	1863.0	1862.2
1.57	1866.2	1865.8	1865.4	1864.8
1.57	1868.3	1867.9	1867.7	1867.3
1.67	1870.3	1869.5	1869.0	1868.1
1.76	1870.9	1870.1	1869.6	1868.6
1.93	1871.5	1870.6	1870.2	1869.3
1.98	1871.7	1870.9	1870.5	1869.7
1.98	1872.1	1871.7	1871.3	1869.7
2.02	1872.1	1871.7	1871.3	1870.0
2.06	1872.1	1871.7	1871.3	1870.0
2.08	1872.3	1871.8	1871.4	1870.1
2.08	1874.4	1873.9	1872.7	1870.2
2.10	1874.4	1873.9	1872.7	1870.2
2.12	1874.5	1873.9	1872.7	1870.4

[1] Channel mile 0.00 is the confluence of the unnamed Main Tributary and the pumped storage pond area at the eastern edge of Williston, commonly referred to as the oxbow area. Water surface profiles were begun using normal flow depth conditions for each frequency. Outlet elevations are dependent on the pump station capacity. The 100-year water surface at mile 0.00 is estimated at elevation 1,848.5 msl, by the COE.

Mile 2.10 of the U.S. Highway 2 & 85 Ditch = Mile 2.10 of the Main Tributary.

CHANNEL MILES	500-YEAR FREQUENCY	100-YEAR FREQUENCY	50-YEAR FREQUENCY	10-YEAR FREQUENCY
2.59	1895.8	1895.0	1894.4	1893.3
2.69	1897.5	1896.4	1895.5	1894.0
2.77	1898.0	1896.9	1896.0	1894.4
2.85	1898.2	1897.0	1896.1	1894.5
2.94	1898.3	1897.2	1896.4	1895.7
3.03	1899.0	1898.5	1898.3	1897.7
3.10	1902.5	1902.3	1902.3	1901.9
3.19	1911.5	1911.0	1910.7	1908.0
3.32	1916.2	1916.0	1915.9	1915.6

U.S. HIGHWAY 2 & 85 DITCH

2.10	1875.0	1874.6	1874.3	1873.6
2.18	1875.0	1874.6	1874.3	1873.6
2.25	1875.4	1874.9	1874.7	1873.9
2.29	1875.8	1875.4	1875.2	1874.7
2.30	1876.8	1876.3	1876.0	1875.4
2.31	1877.3	1876.9	1876.5	1875.7
2.31	1877.5	1877.0	1876.6	1875.7
2.33	1877.7	1877.2	1876.7	1875.8
2.40	1878.6	1877.8	1877.3	1876.2
2.49	1879.2	1878.3	1877.7	1876.4
2.49	1879.5	1879.2	1879.0	1878.1
2.50	1879.5	1879.2	1879.0	1878.1
2.63	1879.6	1879.2	1879.0	1878.4
2.74	1879.8	1879.4	1879.1	1878.4
2.75	1879.8	1879.4	1879.2	1878.4
2.75	1880.0	1879.5	1879.3	1878.5
2.78	1880.0	1879.6	1879.3	1878.5
2.90	1882.3	1881.8	1881.6	1881.1
2.94	1883.2	1882.6	1882.4	1881.9
2.98	1884.3	1883.9	1883.7	1883.3

EXISTING WORKS OF IMPROVEMENT

Specific stage storage and stage discharge figures for the dam located north of the golf course are listed below. The dam is not considered a work of improvement, it was not built by the city. It does have a significant storage capacity if empty when runoff occurs, but it does not have a drawdown pipe, so it must be considered full at the time of the storm event for study purposes.

ELEVATION (MSL)	DISCHARGE (CFS)	STORAGE (AF)
2013.00	.00	.00
2020.00	.00	1.75
2024.00	.00	5.65
2028.00	.00	13.10
2032.00	.00	28.40
2034.00	.00	40.00
2034.50	40.00	45.00
2035.00	120.00	50.00
2035.50	200.00	55.00
2036.00	300.00	64.40
2038.00	500.00	100.00

Soils in the pool area are predominantly sands and gravels. Being porous, the pool is expected to be normally dry. If the dam is empty when runoff occurs, it has an estimated 40.0 acre foot storage capacity. With a drainage area of 470 acres, the dam stores a maximum of about 1.02 inches of runoff without any discharge. This runoff equates to the volume from an approximate 2.8-inch rainfall, nearly a 10-year/24 hour event.

Downstream effects of the dam, for selected 24-hour rainfalls, are shown below.

GOLF COURSE DAM EFFECTS	10-year	50-year	100-year	500-year
maximum inflow (cfs)	133	249	320	475
maximum outflow (cfs)	74	153	200	280

Stage storage and stage discharge tables for the Sloulin International Airport pond are listed below. This structure also has a significant capacity to detain runoff.

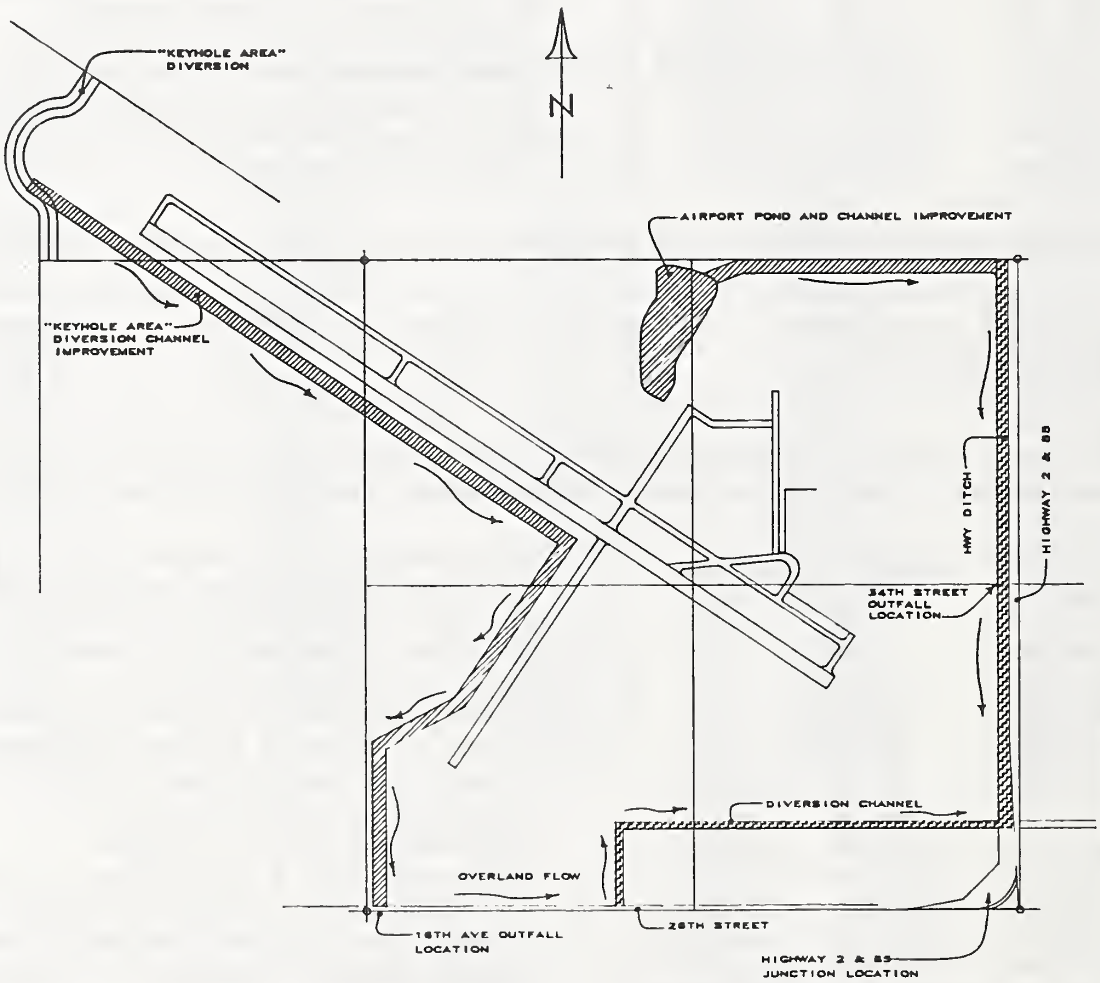
ELEVATION (MSL)	DISCHARGE (CFS)	STORAGE (AF)
1906.00	.00	.00
1907.00	.00	.03
1908.00	28.90	.52
1909.00	34.00	1.83
1910.00	38.40	4.52
1911.00	42.40	8.68
1912.00	48.00	14.44
1913.00	49.30	22.22
1913.10	110.00	23.00
1913.20	220.00	23.70
1913.30	365.00	24.50
1913.40	535.00	25.30
1913.50	725.00	26.10

If the airport pond is empty when runoff occurs, it has an estimated 22.2 acre foot storage capacity at crest elevation. The pond has drawdown pipes to empty the reservoir. With a drainage area of 310 acres, the dam stores a maximum of about 0.85 inch of runoff at crest elevation. This runoff is the volume from an approximate 2.6-inch rainfall, approximately a 5-year/24-hour event. Hydrographs, for 24 rainfall events through the 100-year frequency, show significant peak discharge reductions.

Downstream effects of the pond, for 24-hour rainfalls studied, are shown below.

AIRPORT POND EFFECTS	10-year	50-year	100-year	500-year
maximum inflow (cfs)	104	194	248	367
maximum outflow (cfs)	38	46	48	149

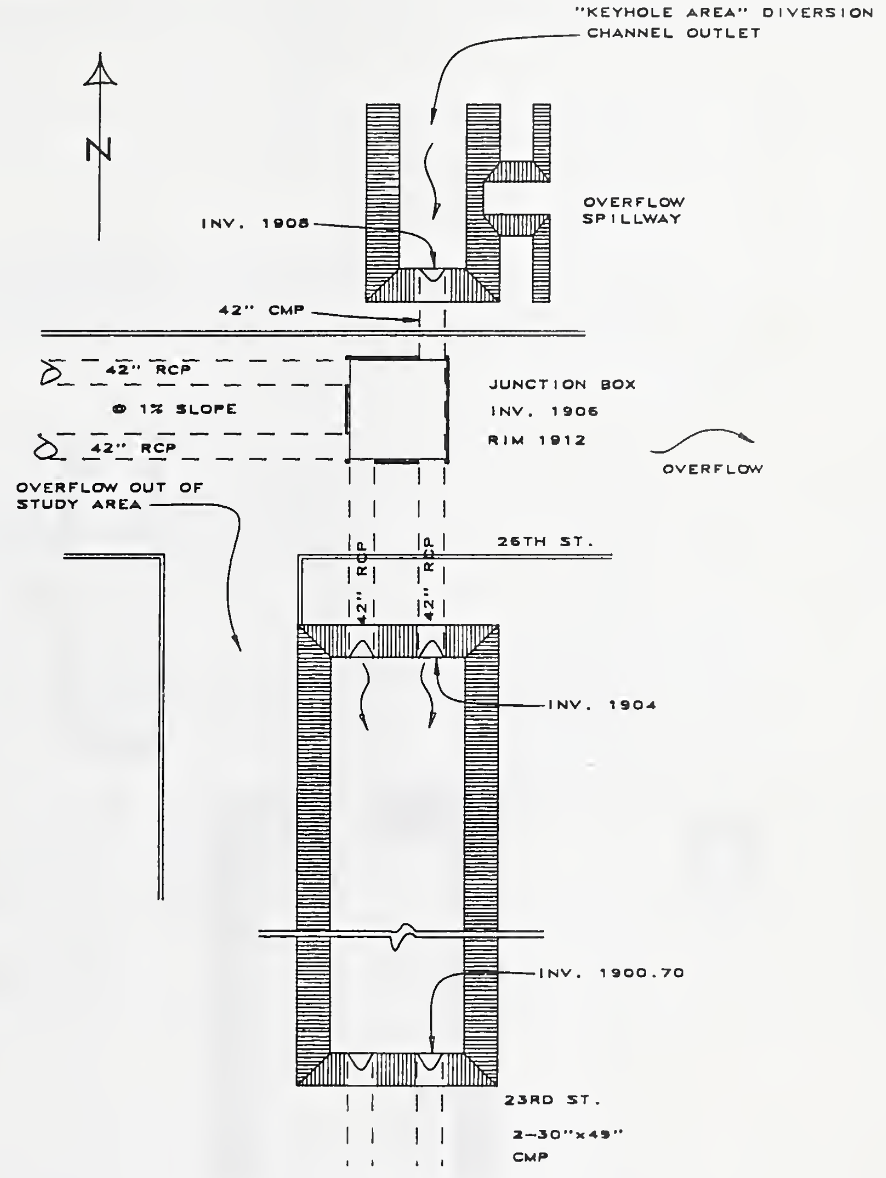
Plan view sketches of existing works of improvement are shown on the following pages. They are provided to show visual representations of existing features described elsewhere in, and used as part of the study. Hydraulic characteristics are also shown, as applicable. The Sloulin International Airport plan view (below) locates improvements, except for the Hagan Slings by Ditch which is located through 26th Street, ½ mile west of the 16th Avenue outfall.



SLOULIN INTERNATIONAL AIRPORT

NOT TO SCALE

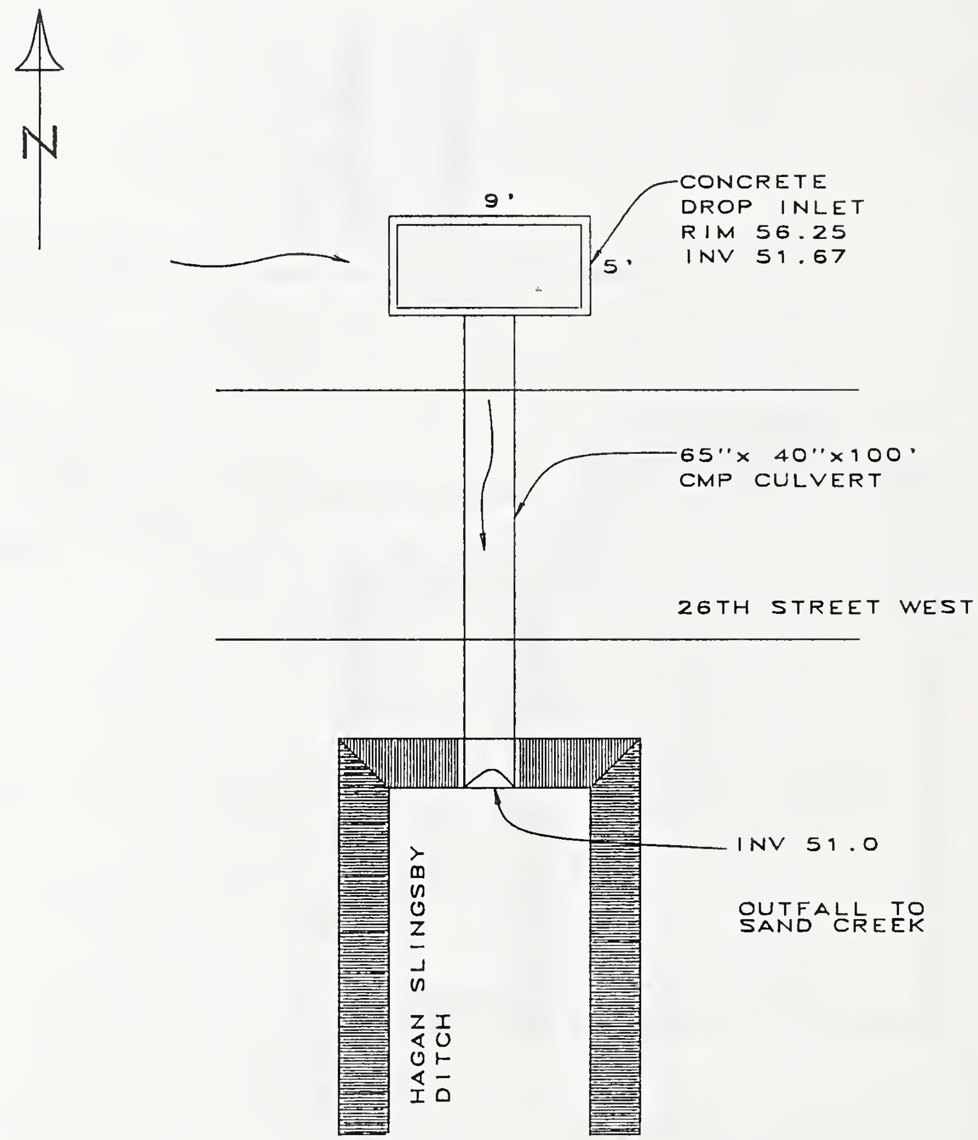
The 16th Avenue Outfall discharges flows south, out of the study area. Flows from twin 42 inch diameter RC pipe (subsurface) and one 42 inch CM pipe (surface) enter a junction box under 26th street. Water exits through twin RC pipe. Capacity is approximately 170 cfs. Excess flows split east and south.



16TH AVENUE OUTFALL

NOT TO SCALE

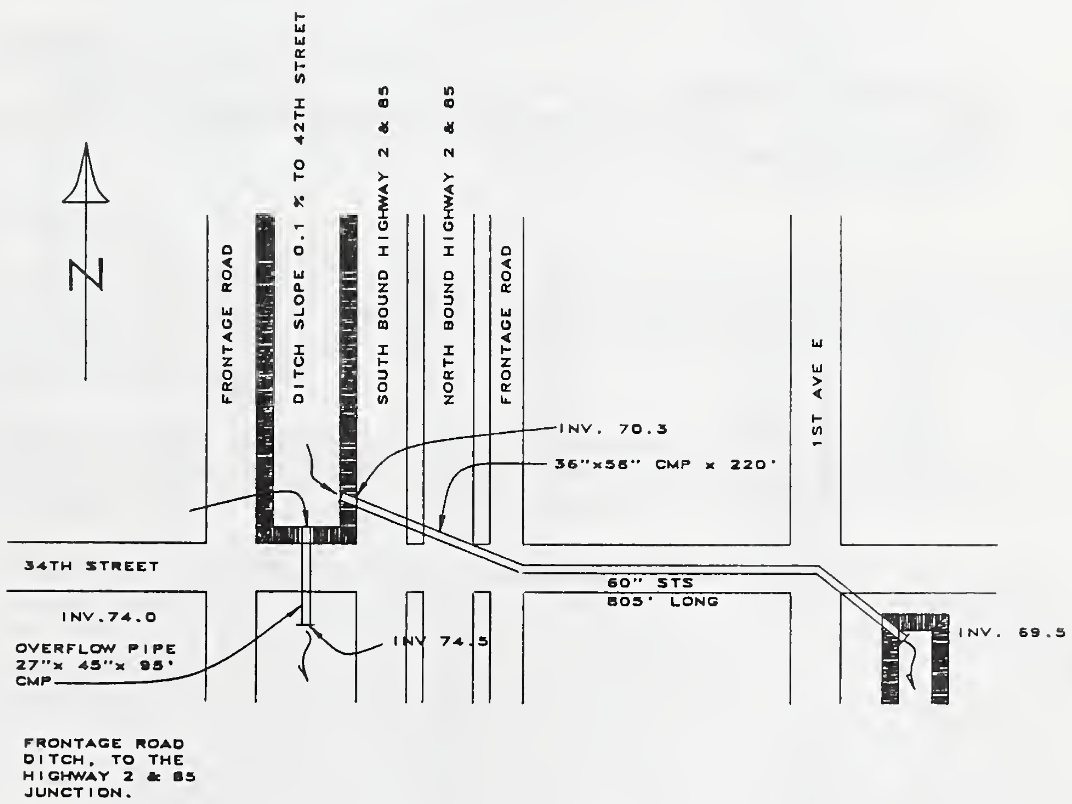
The Hagan Slingsby Ditch diverts about 83 acres from the study area. Total capacity is 120 cfs.



HAGAN SLINGSBY DITCH

NOT TO SCALE

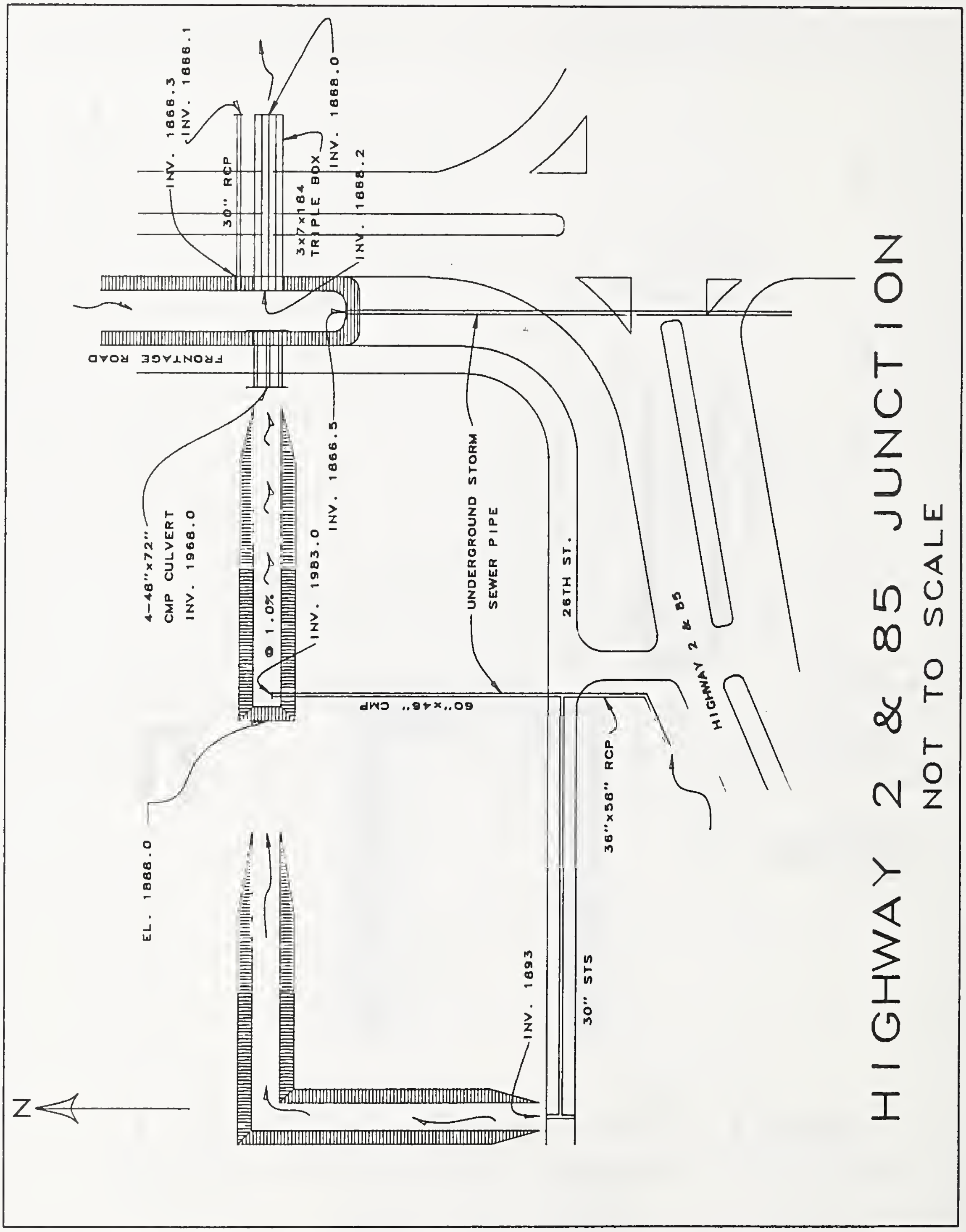
The 34th Street Outfall diverts about 60 cfs from the intersection of 34th street and highway 2 & 85, to the east side of 1st avenue. Flows are then channeled south to the main drainage channel.



34TH STREET OUTFALL

NOT TO SCALE

The Highway 2 & 85 Junction view illustrates how the subsurface pipe and surface channels converge into a common drainage outlet channel near the 26th street intersection.



SOILS

INFORMATION AND AVAILABILITY

The soil information in this report is only for the flood plain area. The soils of Williams County are surveyed. They will be mapped, described, and interpreted in greater detail in the "Soil Survey of Williams County, North Dakota," which is scheduled for printing in December 1993. Copies of the publication will be available after that date from the local Soil Conservation Service Office in Williams County. For unpublished information about the survey prior to December 1993, or help in using soils information, contact the Soil Conservation Service.

INTERPRETATION OF SOILS

Interpretations are given in Table I - Soil Interpretations for Selected Uses on pages H-7 - H-9.

Yields Per Acre

The average yields per acre that can be expected of spring wheat under a high level of management are shown on the table. In any given year, yields may be higher or lower than those indicated in the table because of variations in rainfall and other climatic factors.

The yields are based mainly on the experience and records of farmers, conservationists, and extension agents. Available yield data from nearby counties and results of field trials and demonstrations are also considered.

The management needed to obtain the indicated yields of the various crops depends on the kind of soil and the crop. Management can include drainage, erosion control, and protection from flooding; proper planting and seeding rates; use of suitable high-yielding crop varieties; appropriate and timely tillage; control of weeds, plant diseases, and harmful insects; favorable soil reaction and optimum levels of nitrogen, phosphorus, potassium, and trace elements for each crop; effective use of crop residue, barnyard manure, and green-manure crops; and timely harvesting that ensures highest profits. Dashes indicate crops not grown or not suited to the soil.

Land Capability Classification

Land capability classification shows, in a general way, the suitability of soils for most kinds of field crops. Crops that require special management are excluded. The soils are grouped according to their limitations for field crops, the risk of damage if they are used for crops, and the way they respond to management. The grouping does not take into account major and generally expensive landforming that would change slope, depth, or other characteristics of the soils, nor does it consider possible but unlikely major reclamation projects. Capability classification is not a substitute for interpretations designed to show suitability and limitations of groups of soils for rangeland, woodland, or engineering purposes.

In the capability system, soils are generally grouped as three levels: capability class, subclass, and unit. Only class and subclass are used in this survey. These levels are defined in the following paragraphs.

Capability classes, the broadest groups, are designated by Roman numerals I through VIII. The numerals indicate progressively greater limitations and narrower choices for practical use. The classes are defined as follows:

> Class I soils have slight limitations that restrict their use.
>
> Class II soils have moderate limitations that reduce the choice of plants or require special conservation practices or both.
>
> Class III soils have severe limitations that reduce the choice of plants or require special conservation practices or both.
>
> Class IV soils have very severe limitations that reduce the choice of plants or require very careful management or both.
>
> Class V soils are not likely to erode but have other limitations, impractical to remove, that limit their use.
>
> Class VI soils have severe limitations that make them generally unsuitable for cultivation.
>
> Class VII soils have very severe limitations that make them unsuitable for cultivation.
>
> Class VIII soils have limitations that essentially preclude their use for commercial crop production.

Capability subclasses are soil groups within one class. They are designated by adding a small letter - "e," "w," "s," or "c," to the class numeral, for example, "IIe" or "2e."

The letter "e" shows that the main limitation is risk of erosion unless close growing plant cover is maintained; "w" shows that water in or on the soil interferes with plant growth or cultivation (in some soils the wetness can be partly corrected by artificial drainage); "s" shows that the soil is limited mainly because it is shallow, droughty, or stony; and "c," used in only some parts of the United States, shows that the chief limitation is climate that is very cold or very dry.

In Class I, there are no subclasses because the soils of this class have few limitations. Class V contains only the subclasses indicated by "w," "s," or "c," because the soils in Class V are subject to little or no erosion. They have other limitations that restrict their use to pasture, rangeland, woodland, wildlife habitat, or recreation.

<u>Important Farmland</u>

Prime farmland is one of several kinds of important farmlands defined by the U.S. Department of Agriculture. It is of major importance in providing the nation's short and long-range needs for food and fiber. Prime farmland is the land best suited to producing food, feed, forage, fiber, and oilseed crops. Prime farmland may be in pastureland, cropland, woodland, or other land but is not urban or built-up land or water areas.

Soil Uses and Limitations

The soils are rated in the Soil Interpretation Table according to limitations that affect their suitability for playgrounds, picnic areas, dwellings with basements, septic tank absorption fields, sewage lagoons, fill materials for embankments, and topsoil. The ratings are based on restrictive soil features such as wetness, slope, and texture of the surface layer. Susceptibility to flooding is considered. Not considered in the ratings, but important in evaluating a site, are the location and accessibility of the area, the size and shape of the area, its scenic quality, vegetation, access to water, potential water impoundment sites, and access to public sewer lines. The capacity of the soil to absorb septic tank effluent and the ability of the soil to support vegetation are also important. Soils subject to flooding are limited for recreation use by the duration and intensity of flooding and the season when flooding occurs. In planning recreation facilities, onsite assessment of the height, duration, intensity, and frequency of flooding is essential.

The degree of soil limitation is expressed as slight, moderate, or severe. Slight means that soil properties are generally favorable and that limitations can be overcome or alleviated by planning, designing, or special maintenance. Severe means that soil properties are unfavorable and that limitations can be offset only by costly soil reclamation, special design, intensive maintenance, limited use, or by a combination of these measures.

Dwellings

Ratings are made for small dwellings with basements on undisturbed soil. The ratings are based on soil properties, site features, and observed performance of the soils. A high water table, flooding, shrink-swell potential, and organic layers can cause the movement of footings. A high water table, depth to bedrock or to a cemented pan, large stones, and flooding affect the ease of excavation and construction. Landscaping and grading that require cuts and fills of more than 5 to 6 feet are not considered.

Septic Tank Absorption Fields

Septic tank absorption fields are areas in which effluent from a septic tank is distributed into the soil through subsurface tiles or perforated pipe. Only that part of the soil between depths of 24 to 72 inches is evaluated. The ratings are based on soils properties, site features, and observed performance of the soils. Permeability, a high water table, depth to bedrock or a cemented pan, and flooding affect absorption of the effluent. Large stones and bedrock, or a cemented pan interfere with installation.

Playgrounds

Playgrounds require soils that can withstand intensive foot traffic. The best soils are almost level and are not wet or subject to flooding during the season of use. The surface is free of stones and boulders, is firm after rains, and is not dusty when dry. If grading is needed, the depth of the soil over bedrock or a hardpan should be considered.

Picnic Areas

Picnic areas are subject to heavy foot traffic. Most vehicular traffic is confined to access roads and parking areas. The best soils for picnic areas are firm when wet; are not dusty when dry; are not subject to flooding during the period of use; and do not have slopes, stones, or boulders that increase the cost of shaping sites or of building access roads and parking areas.

Sewage Lagoons

Sewage lagoons are shallow ponds constructed to hold sewage while aerobic bacteria decompose the solid and liquid wastes. Lagoons should have a nearly level floor surrounded by cut slopes or embankments of compacted soil. Lagoons generally are designed to hold the sewage within a depth of 2 to 5 feet. Nearly impervious soil material for the lagoon floor and sides is required to minimize seepage and contamination of ground water.

The table gives ratings for the natural soil that makes up the lagoon floor. The surface layer and generally 1 to 2 feet of soil material below the surface layer are excavated to provide material for the embankments. The ratings are based on soil properties, site features, and observed performance of the soils. Considered in the ratings are slope, permeability, a high water table, depth to bedrock or to a cemented pan, flooding, large stones, and content of organic matter.

Excessive seepage due to rapid permeability of the soil or a water table that is high enough to raise the level of sewage in the lagoon causes a lagoon to function unsatisfactorily. Pollution results if seepage is excessive or if floodwater overtops the lagoon. A high content of organic matter is detrimental to proper functioning of the lagoon because it inhibits aerobic activity. Slope, bedrock, and cemented pans can cause construction problems and large stones can hinder compaction of the lagoon floor.

Embankment, Dikes, and Levees

Embankment, dikes, and levees are raised structures of soil material constructed to impound water or to protect land against overflow. In this table, the soils are rated as a source of fill material below the surface layer to a depth of about 5 feet. It is assumed that soil layers will be uniformly mixed and compacted during construction.

The ratings do not indicate the ability of the natural soil to support an embankment. Soil properties to a depth even greater than the height of the embankment can affect performance and safety of the embankment. Generally, deeper onsite investigation is needed to determine these properties.

Soil material in embankments must be resistant to seepage, piping, and erosion, and have favorable compaction characteristics. Unfavorable features include less than 5 feet of suitable material and a high content of stones or boulders, organic matter, salts, or sodium. A high water table affects the mount of usable material.

Topsoil

Topsoil is used to cover an area so that vegetation can be established and maintained. The upper 40 inches of a soil is evaluated for use as topsoil. Also evaluated is the reclamation potential of the borrow area.

Plant growth is affected by toxic material and by such properties as soil reaction, available water capacity, and fertility. The ease of excavating, loading, and spreading is affected by rock fragments, slope, water table, soil texture, and thickness of suitable material. Reclamation of the borrow area is affected by slope, water table, rock fragments, bedrock, and toxic material.

Soils rated good have friable loamy material to a depth of at least 40 inches. They are free of stones and cobbles, have little or no gravel, and have slopes of less than 8 percent. They are low in content of soluble salts, are naturally fertile or respond well to fertilizer, and are not so wet that excavation is difficult.

Soils rated fair are sandy soils; loamy soils that have a relatively high content of clay; soils that have only 20 to 40 inches of suitable material; soils that have an appreciable amount of gravel, stones, or soluble salts; or soils that have slopes of 8 to 15 percent. The soils are not so wet that excavation is difficult.

Soils rated poor are very sandy or clayey; have less than 20 inches of suitable material; have a large amount of gravel, stones or soluble salts; have slopes of more than 15 percent; or have a seasonal water table at or near the surface.

The surface layer of most soils is generally preferred for topsoil because of its organic matter content. Organic matter greatly increases the absorption and retention of moisture and nutrients for plant growth.

WILLISTON FLOOD PLAIN MANAGEMENT STUDY
WILLIAMS COUNTY, NORTH DAKOTA
TABLE I - SOIL INTERPRETATIONS FOR SELECTED USES

Soil Symbol	Soil Name	Capability Class and Subclass	Important Farmland Category 1/	Spring Wheat Yield Bu/Ac 2/	Dwellings 3/ With Basements	Septic Tank 3/ Absorption Fields	Playgrounds	Picnic Areas	Sewage Lagoons 3/	Dikes, Levees, Embankments	Topsoil
10	Divide loam	3s	AFSI	22	Moderate - wetness	Severe - wetness, poor filter	Slight	Slight	Severe - seepage, wetness	Severe - seepage	Poor - too sandy, small stones, area reclaim
13	Harriet silt loam	6s	OL	--	Severe - flooding, wetness	Severe - flooding, wetness, percs slowly	Severe - wetness, percs slowly, excess sodium	Severe - wetness, percs slowly, excess sodium	Severe - flooding	Severe - piping, wetness, excess sodium	Poor - wetness, excess salt, thin layer
	Stirum fine sandy loam	6s	OL	--	Severe - wetness	Severe - wetness, poor filter	Severe - wetness, excess sodium	Severe - excess sodium	Severe - seepage, wetness	Severe - seepage, piping, wetness	Poor - excess salt, excess sodium
14	Lallie silty clay	3w	AFLI	--	Severe - flooding, wetness, shrink-swell	Severe - flooding, wetness, percs slowly	Severe - wetness, flooding	Severe - wetness	Severe - flooding	Severe - hard to pack, wetness	Poor - wetness, too clayey
	Minnewaukan silty clay loam	4s	AFLI	--	Severe - flooding, wetness	Severe - flooding, wetness, poor filter	Severe - wetness, flooding	Severe - wetness	Severe - seepage, flooding, wetness	Severe - seepage, piping, wetness	Small stones, wetness
18B	Hamerly loam	2e	P(wd)	23	Severe - wetness	Severe - wetness, percs slowly	Moderate - wetness, percs slowly	Moderate - wetness, percs slowly	Severe - wetness	Severe - piping	Fair - small stones
	Tonka silt loam	2w			Severe - ponding, shrink-swell swell	Severe - ponding, percs slowly slowly	Severe - ponding	Severe - ponding	Severe - ponding	Severe - ponding	Poor - thin layer, wetness

TABLE I - SOIL INTERPRETATIONS FOR SELECTED USES (Continued)

Soil Symbol	Soil Name	Capability Class and Subclass	Important Farmland Category 1/	Spring Wheat Yield Bu/Ac 2/	Dwellings 3/ With Basements	Septic Tank 3/ Absorption Fields	Playgrounds	Picnic Areas	Sewage Lagoons 3/	Dikes, Levees, Embankments	Topsoil
31	Williams loam	2c	AFSI	31	Moderate - shrink-swell	Severe - percs slowly	Slight	Slight	Moderate - seepage	Moderate - piping	Good
	Bowbells loam	2c			Moderate - shrink swell	Severe - percs slowly	Slight	Slight	Moderate - seepage	Moderate - piping	Good
31B	Williams loam	2e	AFSI	28	Moderate - shrink-swell	Severe - percs slowly	Moderate - slope	Slight	Moderate - seepage, slope	Moderate - piping	Fair - small stones
	Bowbells loam	2e			Moderate - shrink swell	Severe - percs slowly	Moderate - slope	Slight	Moderate - seepage, slope	Moderate - piping	Fair - small stones
33D	Zahl loam	6e	OL	--	Moderate - slope shrink-swell	Severe - percs slowly	Severe - slope	Moderate - slope	Severe - slope	Severe - piping	Fair - too clayey, small stones, slope
	Williams loam	4e		--	Moderate - slope shrink-swell	Severe - percs slowly	Severe - slope	Moderate - slope	Severe - slope	Moderate - piping	Fair - slope
34B	Lehr loam	3e	AFLI	17	Slight	Severe - poor filter	Moderate - slope, small stones	Slight	Severe - seepage	Severe - seepage	Poor - too sandy, small stones, area reclaim
	Williams loam	2e			Moderate - shrink-swell	Severe - percs slowly	Moderate - slope, small stones	Slight	Moderate - seepage, slope	Moderate - piping	Fair - too clayey, small stones
37	Fernuf loam	2c	AFSI	29	Moderate - shrink-swell	Moderate - percs slowly	Slight	Slight	Moderate - seepage	Severe - piping	Fair - too clayey,

TABLE I - SOIL INTERPRETATIONS FOR SELECTED USES (Continued)

Soil Symbol	Soil Name	Capability Class and Subclass	Important Farmland Category 1/	Spring Wheat Yield Bu/Ac 2/	Dwellings 3/ With Basements	Septic Tank 3/ Absorption Fields	Playgrounds	Picnic Areas	Sewage Lagoons 3/	Dikes, Levees, Embankments	Topsoil
54	Lohler silty clay	2e	AFSI	28	Severe - shrink swell	Severe - wetness, percs slowly	Moderate - too clayey	Moderate - too clayey	Sl	Severe - hard to pack	Poor - too clayey,
63B	Tally fine sandy loam	3e	AFSI	19	Slight	Slight	Moderate - slope, small stones	Slight	Severe - seepage	Severe - seepage piping	Fair, small stones
65B	Appam sandy loam	3e	AFLI	14	Slight	Severe - poor filter	Moderate - slope, small stones	Slight	Severe - seepage	Severe - seepage piping	Poor, too sandy
97	Pits, sandy and gravel	8s	OL	--	--	--	--	--	--	--	--

1/ P = prime, P(wd) = prime where drained, AFSI = additional farmlands of statewide importance, AFLI = additional farmlands of local importance, OL = other land.

2/ All yields are for drained areas of the poorly drained and very poorly drained soils.

3/ Construction of dwellings, septic tanks, and sewage lagoons is not recommended in the flood plain. However, if construction is necessary, the developer should consider the flood hazard and soil restrictions presented in this report.

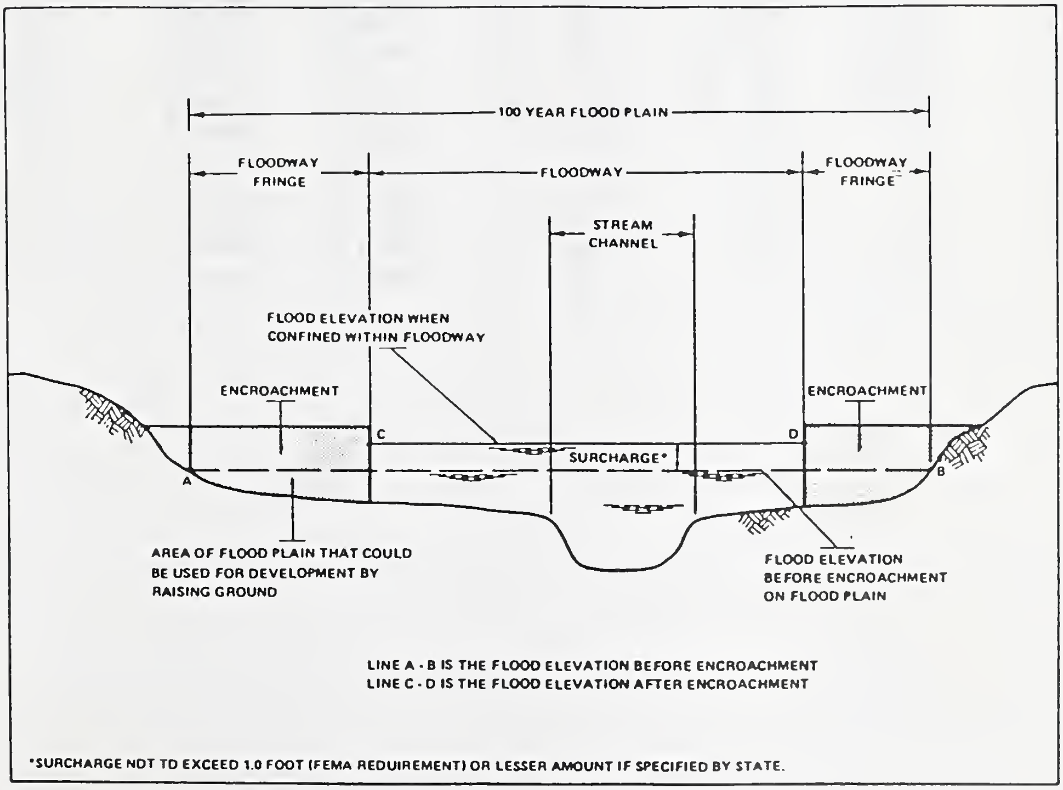
FLOODWAYS

DEFINITIONS

Encroachment on flood plains by structures and/or fill, can reduce the flood carrying capacity, and cause increases in flood heights and flow velocities. The flood hazard may also be increased behind the encroachment. For the purposes of the National Flood Insurance Program (NFIP), a floodway is used as a tool for local administrators to measure the effects of flood plain development on flood heights.

FEMA normally requires a community to designate a part of the flood plain as "regulatory floodway" to avoid the possibility of significantly increasing upstream flood elevations. The floodway is the channel of the stream, plus any adjacent overbank areas, that must be kept free of encroachment so that the 100-year flood can be carried without any increase in flood heights. This "regulatory floodway" does not allow a cumulative increase in the water surface elevation of the base flood of more than 1 foot at any point.

The area between the floodway and 100-year flood plain boundaries is termed the floodway fringe. The floodway fringe encompasses the portion of the floodplain that could be completely obstructed without increasing the water surface elevation of the 100-year flood by more than 1 foot at any point. Typical relationships between the floodway and the floodway fringe and their significance to flood plain development are shown in the following schematic drawing.



FLOODWAY SCHEMATIC

FLOODWAY DATA

MAIN TRIBUTARY

CHANNEL MILE	FLOODWAY section width (ft.)	FLOODWAY x-section area (ft2)	FLOODWAY mean velocity (ft/sec)	WATER SURFACE ELEVATION with floodway (msl)	WATER SURFACE ELEVATION without floodway (msl)	WATER SURFACE ELEVATION elevation difference (ft.)
0.44	260	505	3.04	1848.9	1848.6	0.3
0.56	260	477	3.38	1849.5	1848.9	0.6
0.70	260	591	2.78	1850.1	1849.3	0.8
0.83	260	1028	1.16	1850.3	1849.4	0.9
0.94	260	840	1.45	1850.4	1849.6	0.8
0.97	260	614	2.28	1850.5	1849.8	0.7
1.02	100	857	1.39	1857.3	1857.3	0.0
1.12	100	479	2.59	1857.5	1857.4	0.1
1.18	100	393	3.11	1857.7	1857.6	0.1
1.30	100	425	2.72	1861.3	1861.1	0.2
1.42	100	413	2.92	1861.7	1861.2	0.5
1.51	100	196	5.70	1863.7	1863.3	0.4
1.67	100	194	4.47	1869.8	1869.5	0.3
1.76	100	243	3.57	1870.5	1870.1	0.4
1.93	100	302	2.83	1871.2	1870.6	0.6
2.02	60	193	3.89	1871.9	1871.7	0.2
2.06	60	193	3.89	1871.9	1871.7	0.2
2.10	60	272	2.79	1874.0	1873.9	0.1
2.24	60	57	5.52	1878.5	1878.2	0.3
2.33	60	63	5.00	1883.6	1882.9	0.7
2.49	60	65	4.82	1892.0	1891.8	0.2
2.59	60	65	4.85	1895.1	1895.0	0.1
2.69	60	101	3.11	1896.4	1896.4	0.0
2.77	60	111	2.86	1896.9	1896.9	0.0
2.85	60	235	1.34	1897.1	1897.0	0.1
2.94	60	134	2.35	1897.6	1897.2	0.4
3.03	60	87	3.64	1899.2	1898.5	0.7
3.10	60	74	4.22	1902.9	1902.3	0.6

HIGHWAY 2 and 85 DITCH

CHANNEL MILE	FLOODWAY section width (ft.)	x-section area (ft2)	mean velocity (ft/sec)	WATER SURFACE ELEVATION with floodway (msl)	without floodway (msl)	elevation difference (ft.)
2.10	60	272	2.79	1874.0	1873.9	0.1
2.10	50	223	1.71	1874.60	1874.60	0.0
2.14	50	153	2.52	1874.60	1874.60	0.0
2.18	50	130	2.92	1874.90	1874.60	0.3
2.21	50	115	3.29	1875.30	1874.70	0.6
2.25	50	121	3.14	1875.70	1874.90	0.8
2.29	50	85	4.50	1876.40	1875.40	1.0
2.30	50	85	4.58	1876.80	1876.30	0.5
2.33	50	141	2.70	1877.60	1877.20	0.4
2.37	50	139	2.77	1877.80	1877.50	0.3
2.40	50	155	2.50	1878.00	1877.80	0.2
2.44	50	157	2.47	1878.10	1878.10	0.0
2.47	50	140	1.43	1878.30	1878.30	0.0
2.50	50	274	0.73	1879.20	1879.20	0.0
2.52	50	279	0.93	1879.20	1879.20	0.0
2.56	50	254	1.03	1879.20	1879.20	0.0
2.59	50	255	1.02	1879.20	1879.20	0.0
2.63	50	240	1.09	1879.20	1879.20	0.0
2.67	50	236	1.10	1879.20	1879.20	0.0
2.71	50	222	1.17	1879.30	1879.30	0.0
2.72	50	212	1.23	1879.30	1879.30	0.0
2.74	50	89	2.15	1879.30	1879.30	0.0
2.78	50	183	1.42	1879.60	1879.60	0.0
2.82	50	105	2.49	1879.80	1879.80	0.0
2.86	50	62	4.19	1880.90	1880.90	0.0
2.90	50	72	3.64	1881.80	1881.80	0.0
2.93	50	74	3.91	1882.60	1882.60	0.0
2.97	50	61	4.30	1884.00	1884.00	0.0

EXISTING BRIDGES AND CULVERTS

Bridges and culverts on the Main Tributary existing at the time of study, and used to develop the water surface profile data contained in this document, are shown pictorially on the following pages. A representative culvert along the U.S. Highway 2 & 85 Ditch is shown.

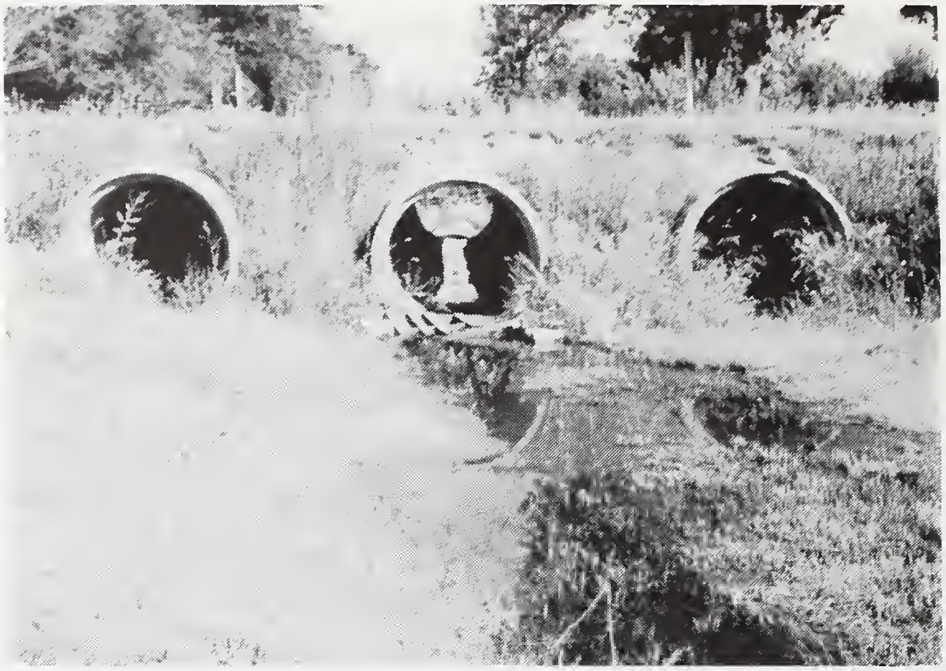
The pictures will be helpful in the future to visually check which bridges and culverts were in place at the time of the study, were restrictive, were in need of replacement, or which have been subsequently replaced, thus affecting localized flood plains.

Potential flood stages are also shown, for the 100-year and 500-year events, at existing bridges and culverts pictured.

MILE 0.99 - EAST BYPASS
NE¼ SECTION 13, T154N, R101W

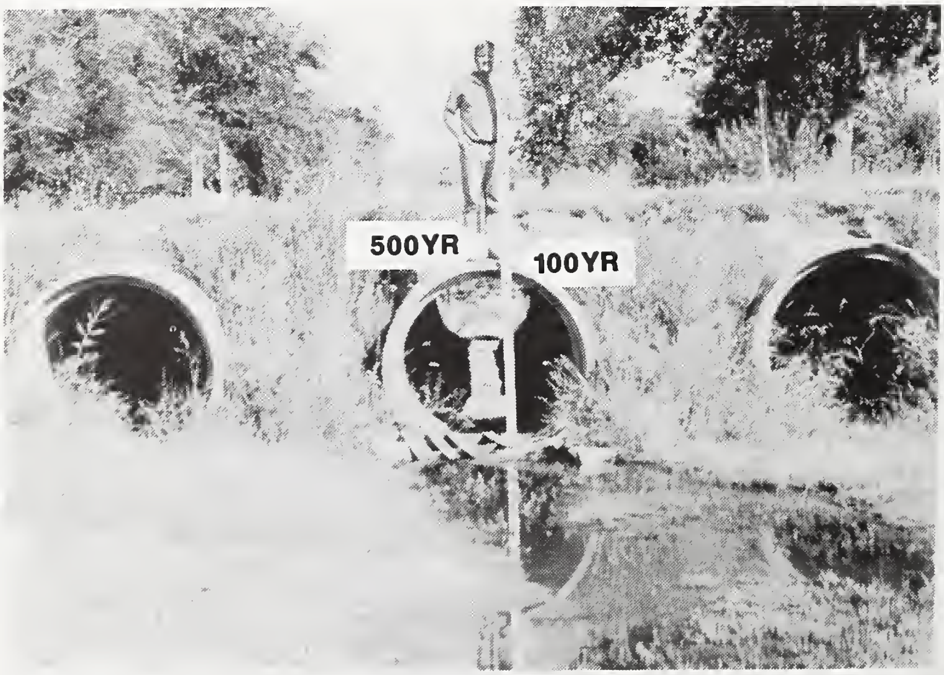
Looking Downstream

MILE 1.22 - 26TH AVENUE EAST
SE¼ SEC.12, NE¼ SEC.13, T154N, R101W
Looking Downstream



MILE 1.57 - UNIVERSITY AVENUE
SW¼-SE¼ SECTION 12, T154N, R101W

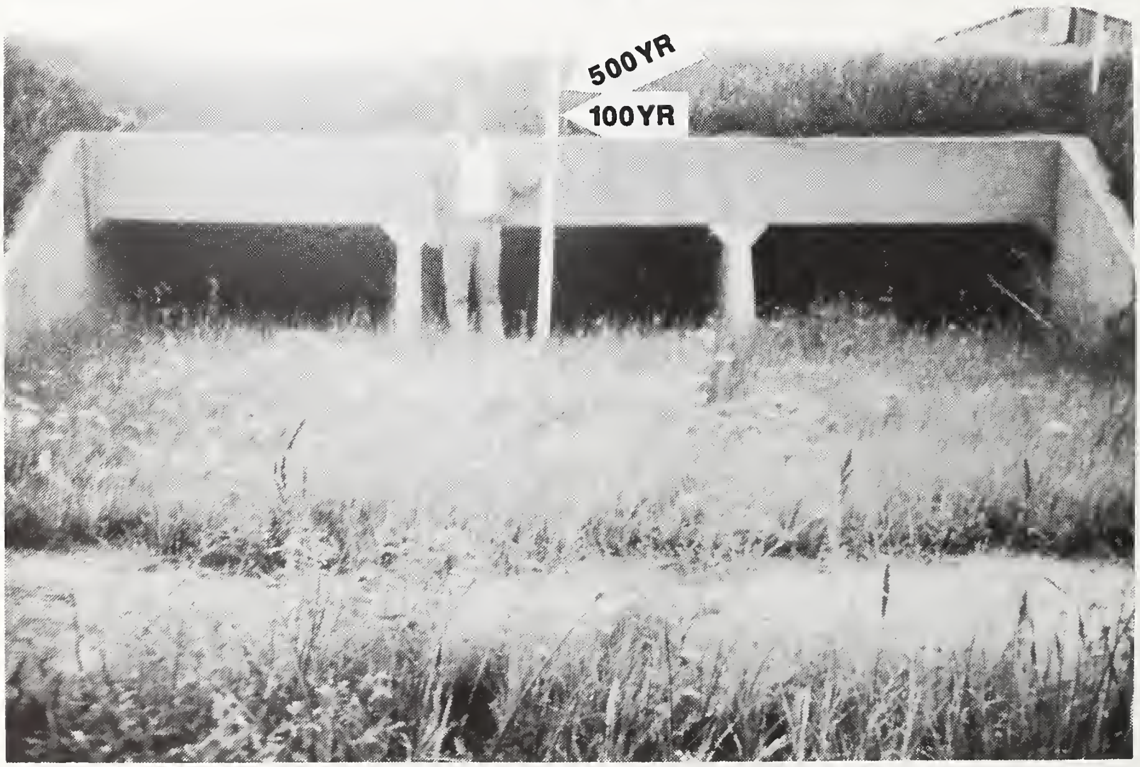
Looking Downstream



MILE 1.98 - 1ST AVENUE WEST
SW¼ SECTION 12, T154N, R101W
Looking Downstream

MILE 2.08 - HIGHWAY 2 AND 85
SW¼ SEC.12, SE¼ SEC.11, T154N, R101W

Looking Downstream



MILE 2.12 - WEST FRONTAGE ROAD
SE¼ SECTION 11, T154N, R101W

Looking Downstream

MILE 3.19 - 16TH AVENUE WEST
SW¼ SEC.11, SE¼ SEC.10, T154N, R101W

Looking Upstream

ELEVATION REFERENCE MARKS

R.M. No.	ELEVATION	R.M. DESCRIPTION
WILL-90-001	1850.59	TOP OF HYDRANT, NW COR 14TH AVE E AND 18TH STREET.
WILL-90-002	1850.16	SPIKE IN THE 4TH POWER POLE SOUTH OF THE NE COR LOT#1, BLK#5, ROSAAEN SUBDIVISION.
WILL-90-003	1849.00	SPIKE IN THE 3RD POWER POLE NORTH OF THE NE COR LOT#1, BLK#5, ROSAAEN SUBDIVISION.
WILL-90-005	1860.35	TOP OF HYDRANT, SW COR EAST DAKOTA PARKWAY AND 22TH STREET.
WILL-90-006	1864.52	TOP OF HYDRANT, SW COR 9TH AVE EAST AND 24TH STREET.
312A	1902.23	USC&GS STANDARD DISC, STAMPED 312A-1965, SW COR AIRPORT OFFICE, BRASS CAP SET IN CONCRETE STEP.